STAFF
CLIMATE
NOTES

Climate Challenges in Fragile and Conflict-Affected States

Laura Jaramillo, Aliona Cebotari, Yoro Diallo, Rhea Gupta,
Yugo Koshima, Chandana Kularatne, Daniel Jeong Dae Lee,
Sidra Rehman, Kalin Tintchev, and Fang Yang

IMF STAFF CLIMATE NOTE 2023/001

Climate Challenges in Fragile and Conflict-Affected States

IMF Staff Climate Note 2023/001

Laura Jaramillo, Aliona Cebotari, Yoro Diallo, Rhea Gupta, Yugo Koshima, Chandana Kularatne,
Daniel Jeong Dae Lee, Sidra Rehman, Kalin Tintchev, and Fang Yang*

DISCLAIMER: The IMF Notes Series aims to quickly disseminate succinct IMF analysis on critical economic issues to member countries and the broader policy community. The IMF Staff Climate Notes provide analysis related to the impact of climate change on macroeconomic and financial stability, including on mitigation, adaptation, and transition. The views expressed in IMF Staff Climate Notes are those of the author(s), although they do not necessarily represent the views of the IMF, or its Executive Board, or its management. The boundaries, colors, denominations, and any other information shown on maps do not imply, on the part of the IMF, any judgment on the legal status of any territory or any endorsement or acceptance of such boundaries.

RECOMMENDED CITATION: Jaramillo, Laura, Aliona Cebotari, Yoro Diallo, Rhea Gupta, Yugo Koshima, Chandana Kularatne, Daniel Jeong Dae Lee, Sidra Rehman, Kalin Tintchev, and Fang Yang. 2023. "Climate Challenges in Fragile and Conflict-Affected States." IMF Staff Climate Note 2023/001, International Monetary Fund, Washington, DC.

ISBN:	979-8-40025-208-2 (Paper) 979-8-40025-211-2 (Web PDF) 979-8-40025-223-5 (ePub)	
JEL Classification Numbers:	Q54; D74; Q15; O43	
Keywords:	fragile and conflict-affected states; climate change; natural disasters; conflict; food security; adaptation; resilience; climate finance	
Authors' email addresses:	ljaramillomayor@imf.org acebotari@imf.org ydiallo2@imf.org rgupta5@imf.org ykoshima@imf.org	ckularatne@imf.org JLee8@imf.org srehman@imf.org ktintchev@imf.org fyang@imf.org

---

* The authors gratefully acknowledge guidance and feedback from Jihad Azour, Abe Selassie, Taline Koranchelian, Cathy Pattillo, and Andrea Richter. The analysis on conflict intensity benefited from expertise on high frequency data and insights from Jiaxiong Yao. We are grateful for contributions from Lamiae Agoumi, and comments and suggestions from Jamal Saghir, Lindsey Jones, IMF country teams, and participants of departmental seminars in MCD and AFR. The paper also benefited from very useful comments from IMF departments during the review process. We are grateful to colleagues from the World Bank and Executive Directors' offices for their suggestions. We are also very grateful for excellent support by Felicite Adjahouinou, Geraldine Cruz, and Oksana Ament.

Climate Challenges in Fragile and Conflict-Affected States

Laura Jaramillo, Aliona Cebotari, Yoro Diallo, Rhea Gupta, Yugo Koshima, Chandana Kularatne, Daniel Jeong Dae Lee, Sidra Rehman, Kalin Tintchev, and Fang Yang.

August 2023

Summary

About one in five countries around the world are considered to be fragile and conflict-affected states (FCS). FCS are home to nearly 1 billion people and 43 percent of the world's poor. Using innovative approaches, this note finds that in FCS, climate vulnerability and underlying fragilities—namely conflict, heavy dependence on rainfed agriculture, and weak capacity and policy buffers—exacerbate each other, amplifying the negative impact on people and economies.

FCS will disproportionately suffer from climate change, including because of their geographical location and dependence on agriculture. Since 1980, the median FCS has faced disruptive extreme weather events in one out of every four years, with little time to fully recover before a new disaster hit. FCS already face higher temperatures than other countries and will be more exposed to extreme heat going forward. Forecasts suggest that climate change will lead to an even higher number of days at extremely high temperatures that will endanger human health. By 2040–59, the median FCS will face 61 days/year of temperatures above 35 degrees Celsius, compared to only 15 days for other countries under a high emissions scenario. Climate change will also affect FCS because of overreliance on climate-dependent sectors (particularly agriculture), the precarity of urban infrastructure (including because of populations pushed into flood- and landslide-prone areas), and limited access to safe drinking water and sanitation.

GDP losses due to climate shocks are more severe and persistent in FCS than in other countries. In the near term, cumulative GDP losses are estimated at about 4 percent in FCS after three years of a disruptive extreme weather event, compared to about 1 percent in other countries. Over the longer term, worsening drought conditions are found to have a larger and more persistent impact in FCS than non-FCS, which means that incomes in FCS would fall further and further behind other countries. Worsening drought conditions in FCS would cut real GDP per capita growth every year by 0.2 percentage point in a low emissions scenario and 0.4 percentage point in a high emissions scenario. By 2060, real GDP per capita in FCS would be 5 percent lower in the high emissions scenario compared to the low emissions scenario.

Drought will increase hunger in FCS, from already high levels. Food production in FCS is found to be two times more sensitive to drought conditions over the longer term than in non-FCS countries. Worsening drought conditions are also associated with persistent upward pressure on inflation in FCS, as food represents a large share of their consumption. Looking forward, the confluence of lower food production and higher prices in a high emissions scenario would push 2 percentage points more of fragile states' population—more than 50 million people—into hunger by 2060.

Climate shocks have a grave impact on humanitarian conditions in FCS. Three times as many people in FCS are affected every year by extreme weather events than in other countries. Close to 10 percent of internal displacement in FCS is directly linked to disasters, with more than twice the share of

the population being displaced in FCS than in other countries. It is also striking that close to 95 percent of refugees, 86 percent of internally displaced people, and 20 percent of migrants globally have originated in FCS. While forced displacement and migration have a number of complex drivers, climate change is an increasingly important factor.

Climate shocks significantly worsen conflict, compounding fragility. While climate shocks may not trigger the onset of new conflict (as conflicts derive from a complex range of factors), climate shocks exacerbate conflict intensity where it already exists. Estimations indicate that in a high emissions scenario, and all else equal, by 2060 conflict deaths as a share of the population for a median FCS could increase by 8.5 percent, and up to 14 percent in countries facing an extreme increase in temperature.

Agriculture is crucial for FCS economies but is highly vulnerable to climate shocks, including because of heavy dependence on rainfed agriculture. Value added of the agriculture sector represents close to one-quarter of GDP for the median FCS, but only 3 percent of cultivated areas in FCS are equipped for irrigation. In contrast to irrigated farms, rainfed farms are highly susceptible to volatility in rainfall and groundwater, as well as floods. Rainfed farms in FCS stand to lose 11 percent of their agriculture production (as proxied by farmland vegetation) when a rainy season disappoints, which will become more commonplace as climate change increases the variability of precipitation.

Moreover, case studies illustrate how different sources of fragility amplify the impact of climate shocks in FCS by damaging scarce irrigation infrastructure and agricultural production. For instance, FCS face (1) damage and abandonment of irrigation systems by conflict; (2) inadequate maintenance because of lack of resources and capacity, although there is a strong payoff of efforts to recover damaged irrigation infrastructure; (3) unworkable projects or polices because of poor design, planning, or implementation; and (4) weak oversight and governance of projects.

It is crucial that FCS implement policies for climate adaptation. Macro-critical policies to facilitate the immediate response to climate shocks include (1) building buffers—in particular fiscal buffers and international reserves—and strengthening institutional capacity to facilitate robust emergency responses; (2) strengthening social safety nets; and (3) transferring disaster risk through sovereign insurance, where cost-effective. Policies to build climate resilience over time include (1) embedding climate resilience into efforts to improve peace and security, (2) improving governance and fighting corruption, (3) developing climate-smart agriculture, (4) scaling up social spending and climate-resilient infrastructure investments, and (5) enhancing financial inclusion. Overall, given the complexities, climate adaptation policies need to follow a multidimensional approach that is carefully prioritized and tailored to specific contexts and local communities and that supports conflict prevention and resolution.

Sizable and sustained international support—especially through grants, concessional financing and capacity development—is urgent to avoid worse outcomes. International partners must help FCS as a global public good—or else spillover effects associated with fragility and conflict could become even more disruptive, including more forced displacement and migration to other countries. The financing needed for climate adaptation is well beyond what FCS can afford on their own. For example, adaptation costs for FCS are about 1.5 percent of GDP per year, compared to 1 percent of GDP in other countries. Financing climate adaptation is less costly than financing frequent disaster and humanitarian relief, but so far international financing for climate adaptation has fallen short of what is needed. In addition to international financing and support for adequate sovereign insurance coverage, FCS need technical assistance and training to strengthen their capacity to absorb and spend climate finance effectively.

The IMF is stepping up support to FCS in dealing with climate challenges through carefully tailored policy advice, financing, and capacity development. The IMF has enhanced its financial support for climate action, including the new Resilience and Sustainability Facility. IMF technical assistance and training can help FCS upgrade climate-related skills and better manage risks.

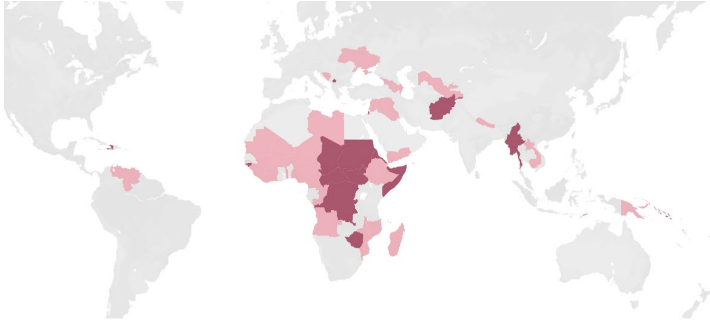
Introduction

Using innovative approaches, this note shows that in fragile and conflict-affected states (FCS), climate vulnerability and underlying fragilities—namely conflict, heavy dependence on rainfed agriculture, and weak capacity and policy buffers—exacerbate each other, amplifying the negative impact on people and economies.

FCS are home to nearly 1 billion people.[1] About one in five countries around the world are considered to be FCS (Figure 1). FCS are a heterogenous group of countries that face a complex set of challenges, including—and to varying degrees—high levels of institutional and social fragility and violent conflict (see Annex 1). Relatedly, FCS have lower per capita income and growth rates, higher poverty and undernourishment, and higher inequality than other countries (Figure 2). Indeed, FCS host 43 percent of the global poor living on less than $2.15 per day while only accounting for 12 percent of the world's population. At the same time, and as illustrated by Figure 3, FCS are highly exposed to climate change and must bear the immense burden of climate adaptation without having the means or capacity to adapt.

Figure 1. Fragile and Conflict Affected States, FY2006–FY2024

Source: Authors, based on the World Bank FCS lists.

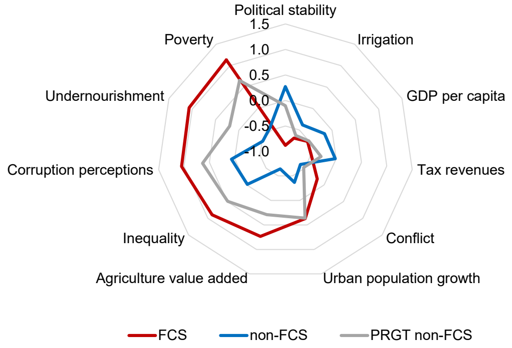


© 2023 Mapbox © OpenStreetMap

Note: Fragile and conflict affected states (FCS) are defined based on the World Bank's country list from FY2006 to FY2024 (Annex 1). The IMF adopted the methodology, thresholds, and criteria of the World Bank's FCS list as part of the FCS strategy approved in 2022. Darker red indicates countries that have been classified as FCS throughout the sample period and lighter red countries classified as FCS at least once.

Figure 2. Different Structural Characteristics across FCS and Non-FCS

(Median across country group; all variables are standardized)



Sources: Food and Agriculture Organization of the United Nations, AQUASTAT; IMF, World Economic Outlook database; Standardized World Income Inequality Database; Transparency International; Uppsala Conflict Data Program; World Bank, World Development Indicators (WDI); World Bank, Worldwide Governance Indicators; and authors' estimates.

Notes: Political stability (Worldwide Governance Indicators), percent of cultivated areas equipped for irrigation (Food and Agriculture Organization of the United Nations, AQUASTAT), GDP per capita (current US$, WDI), tax revenues to GDP (IMF, World Economic Outlook database), number of conflict years since 1980 (Uppsala Conflict Data Program), urban population growth (WDI), agriculture valued added to GDP (WDI), Gini coefficient (Standardized World Income Inequality Database), Corruption Perceptions Index (Transparency International), prevalence of undernourished population (WDI), and poverty headcount ratio at $2.15 a day (2011 purchasing power parity, WDI). FCS = fragile and conflict-affected states; PRGT = Poverty Reduction and Growth Trust.

This note shows that in FCS climate vulnerability and fragility exacerbate each other.[2] Figure 4 provides a simplified framework to illustrate the nexus. For instance, climate shocks exacerbate fragility by worsening conflict as groups compete for scarce resources, diminishing crop yields on rainfed farms, and straining public resources. At the same time, fragilities such as conflict, heavy reliance on rainfed farming, inadequate infrastructure, and weak policy buffers make climate vulnerability worse because they diminish the scope for a robust emergency response in the case of extreme weather events

---

[1] FCS in this paper are defined based on the World Bank's country list, which provides a time series from FY2006 to FY2024 (Annex 1). The IMF adopted the methodology, thresholds, and criteria of the World Bank's FCS list as part of the FCS strategy approved in 2022 (IMF 2022a). Country coverage differs across the different empirical analyses in the note due to the focus and data availability for each section.

[2] Several IMF Country Engagement Strategies underscore the effect of climate shocks in exacerbating fragility and conflict (Democratic Republic of Congo, Guinea-Bissau, Iraq, Somalia, South Sudan, Yemen).

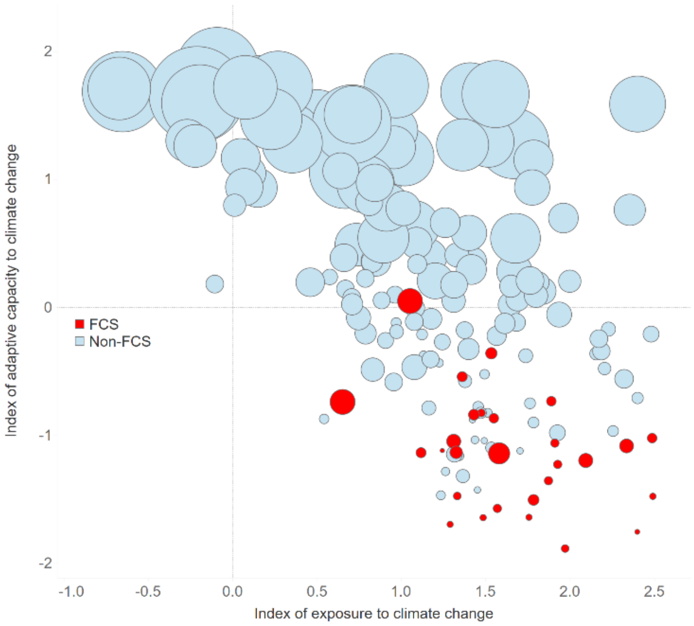
and curtail efforts to build economic resilience. Conflict, in particular, exacerbates climate vulnerability, including because it fuels environmental degradation, erodes people's incomes and assets, and takes resources away from adaptation efforts. Combined, climate vulnerability and fragility impair social and economic outcomes by worsening poverty, hunger, and displacement, while hurting economic development.

The rest of this note is organized as follows. The next section discusses the exposure of FCS to climate shocks. The following section analyzes the impact of climate shocks on macroeconomic outcomes and food security, and examines how this impact differs in FCS from non-FCS.[3] The fourth section assesses the impact of climate shocks on humanitarian outcomes and conflict. The fifth section examines climate vulnerability in agriculture showcasing how climate shocks affect rainfed agriculture but also how underlying fragilities amplify climate shocks in agriculture. The following section outlines macro-critical climate adaptation policies in FCS. The final section discusses the urgent need for international support.

To overcome severe data constraints for FCS, this note uses innovative data and methodologies to shed light on climate vulnerability and fragility. This note uses georeferencing and geospatial analysis to build and analyze high frequency and subregional data sets on FCS, in addition to analyses drawing on country-level macroeconomic data and case studies.

Figure 3. Exposure versus Adaptive Capacity to Climate Change

(Bubble size represents GDP per capita of the country)



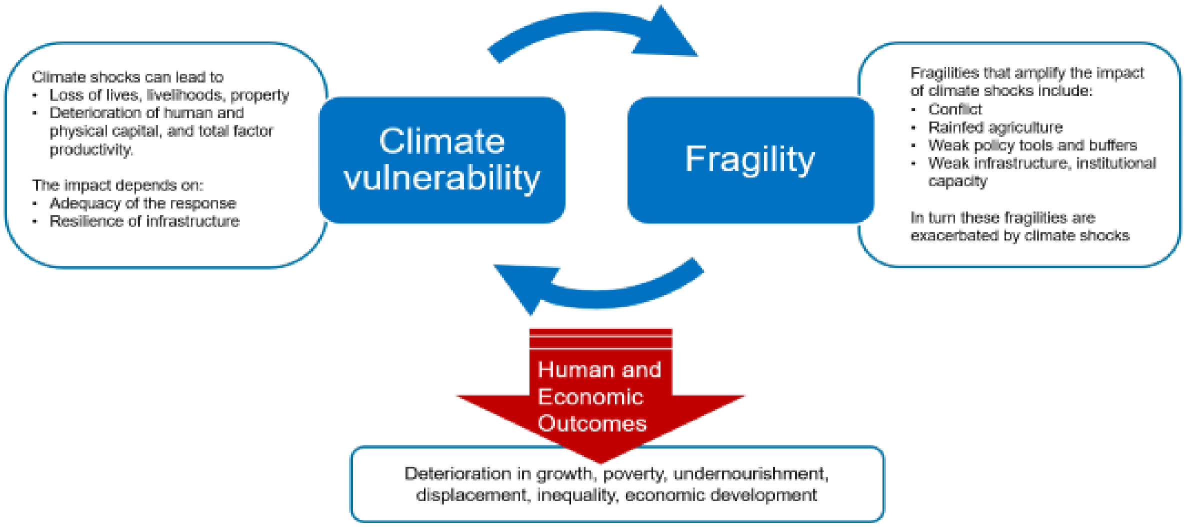
Sources: INFORM Climate Change Risk Index; Notre Dame Global Adaptation Initiative; UN Development Programme, Human Climate Horizons; UN University - Institute for Environment and Human Security, World Risk Index; and authors' calculations.

Note: The exposure index in this note measures exogenous climate change vulnerabilities based on the physical characteristics of extreme weather events and the projected impact of climate change on temperature and rainfall. It is the average of standardized values of the Notre Dame Global Adaptation Initiative exposure subindex, INFORM Risk Index natural hazard exposure subindex, UN Development Programme's Human Climate Horizons projected increase in human deaths, and the World Risk Index climate exposure subindex.
The adaptive capacity index in this note measures climate change vulnerabilities due to socioeconomic, infrastructure, and institutional characteristics. It combines the World Risk Index coping and adaptive capacity subindices and INFORM Risk Index's coping capacity subindex. FCS = fragile and conflict-affected states.

---

[3] In this note, climate shocks refer to extreme weather events (droughts, floods, storms) and the slower-moving impact of changing/more volatile precipitation and temperature.

Figure 4. Climate Vulnerability-Fragility Nexus



Source: Authors.

Exposure of FCS to Climate Shocks

Climate change will have a disproportionate impact on FCS. FCS are expected to be more exposed to extreme heat, which will affect lives and livelihoods, as forecasts show that FCS will see significantly higher increases in temperatures starting from already higher average temperatures than non-FCS. FCS also experience frequent disruptive extreme weather events, which are expected to become more frequent and more severe with climate change.

Climate change will have a disproportionate impact on FCS.[4] Although FCS are not large carbon dioxide emitters and have contributed the least to the climate crisis, they are bearing the burden of climate change.[5] A composite index of exposure to climate change, which combines different sources to capture exogenous climate vulnerabilities based on the physical characteristics of extreme weather events and the projected impact of climate change on temperature and water (Figure 5), shows that FCS are significantly more exposed to climate change than other countries.

- **Extreme heat:** FCS will face significantly higher increases in temperature, starting from already higher average temperatures than non-FCS. While both FCS and non-FCS have been seeing rising temperatures, especially since the 1990s, temperatures in FCS are typically already much higher than in other countries (Figure 6). Moreover, according to UN Development Programme Human Climate Horizons forecasts, by 2040–59, the median FCS will face 61 days of temperatures above 35 degrees Celsius per year (up from 30 days in 1986–2005), compared to only 15 days for other countries (up from 2 days in 1986–2005) under a high emissions scenario (RCP 8.5) (Figure 7). High and rising temperatures endanger human health (increasing heat-related illnesses, such as heat stroke) and are detrimental to labor supply,

---

[4] It is important to note that there is considerable uncertainty around the global emissions trajectory as well as long-term climate and macroeconomic modeling. Predicting future emissions is inherently extremely uncertain, including because of the rapid rate of technological progress. For illustrative purposes, this note draws on models in the Intergovernmental Panel on Climate Change Sixth Assessment Report for a high emissions scenario (Representative Concentration Pathway [RCP] 8.5), a moderate emissions scenario (RCP 4.5), and low emissions scenario (RCP 2.6). RCP 8.5 is on the higher end of the range of possible baseline scenarios that assumes absence of global mitigation efforts in the context of high economic growth and thus high emissions.

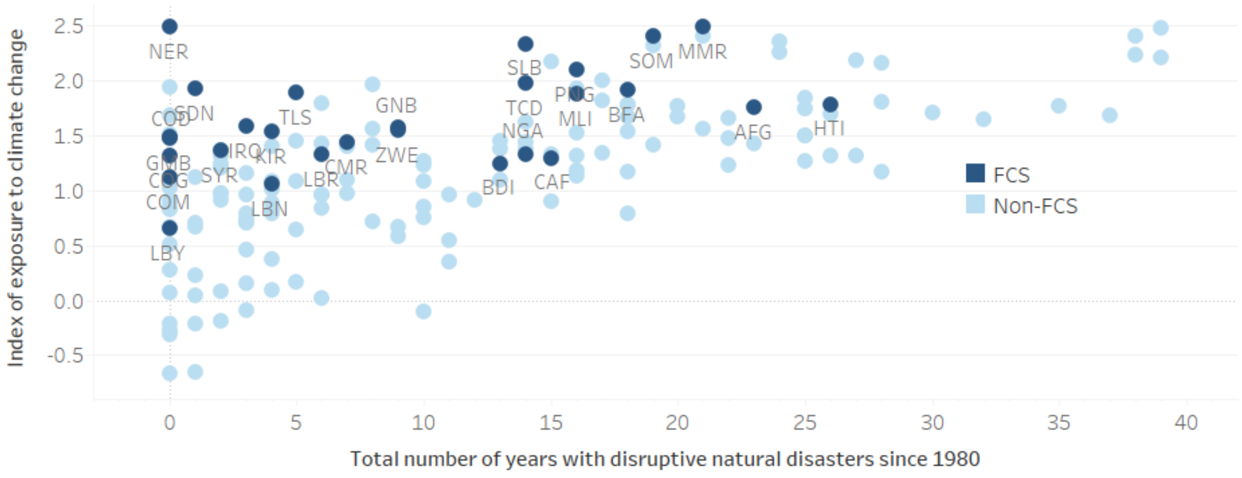
[5] Carbon dioxide emissions per capita in FCS are only a fraction those emitted by other countries, at 0.5 tons for the median FCS in 2021 compared to 3.5 tons for other countries.

for instance leading to a reduction in hours worked in high-risk sectors such as agriculture and construction.[6]

- **Extreme weather events:** FCS already face frequent disruptive extreme weather events, which are expected to become more frequent and more severe with climate change. Centre for Research on the Epidemiology of Disasters, Emergency Events Database data show that the median FCS has faced disruptive extreme weather events in one out of every four years since 1980, which means that these countries had little time to fully recover before a new disaster hit.[7] Floods have been the most frequent type of disaster, followed by storms and droughts. This is comparable to what has been observed in non-FCS.

- **Other exposure:** Other sources of FCS exposure to climate change include heavy reliance on climate-dependent sectors (particularly agriculture), the precarity of urban infrastructure (including because of populations pushed into flood and landslide prone areas—see Box 1), and limited access to safe drinking water and sanitation. Some FCS also are facing rising sea levels that can affect urban centers and major ports.

Figure 5. Number of Years Since 1980 with Disruptive Disasters and Exposure to Climate Change



Sources: Centre for Research on the Epidemiology of Disasters, Emergency Events Database; INFORM Climate Change Risk Index; Notre Dame Global Adaptive Initiative; UN Development Programme, Human Climate Horizon; The University Institute for Environment and Human Security World Risk Index; and authors' calculations.

Note: The exposure index measures exogenous vulnerabilities to climate change based on the physical characteristics of extreme weather events and the projected impact of climate change on temperature and rainfall. The exposure index is the average of standardized values of the Notre Dame Global Adaptive Initiative exposure subindex, INFORM Risk Index natural hazard exposure subindex, UN Development Programme Human Climate Horizons projected increase in human deaths, and the World Risk Index climate exposure subindex. The adaptive capacity index measures the vulnerabilities to climate change due to socioeconomic, infrastructure, and institutional characteristics. This is derived from a combination of World Risk Index coping and adaptive capacity subindices and INFORM Risk Index's coping capacity subindex. See Annex 2 for definition of years with disruptive extreme weather events. Data labels in the figure use International Organization for Standardization (ISO) country codes. FCS = fragile and conflict-affected states.

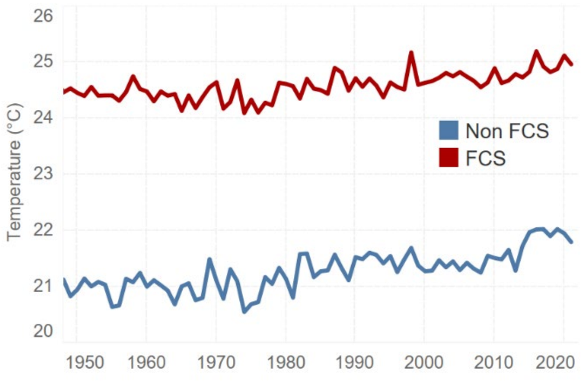
---

[6] Temperature shocks have been found in the literature to have a stronger effect on incomes in hot and low-income countries (Dell, Jones, and Olken 2009; Burke, Hsiang, and Miguel 2015).

[7] Given severe data constraints in FCS, coverage of extreme weather events in FCS is likely to be incomplete.

Figure 6. Temperature, 1950–2022

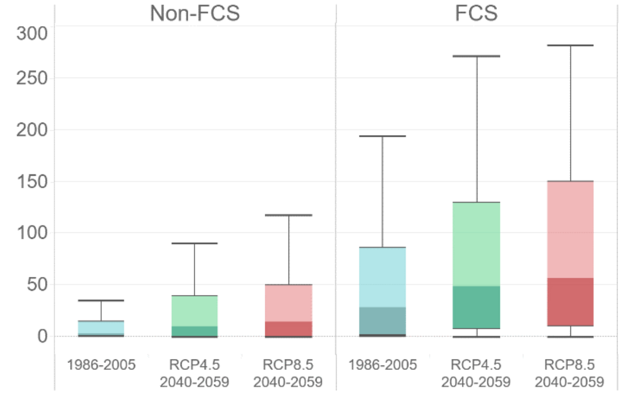
(Degrees Celsius, median across country groups)



Sources: World Bank Climate Change Knowledge Portal; and authors' estimates.
Note: FCS = fragile and conflict-affected states.

Figure 7. Days above 35 Degrees Celsius under Moderate and High Emissions Scenarios

(Annual average)



Sources: UN Development Programme; Human Climate Horizons; and authors' estimates.
Note: Moderate emissions scenario (Representative Concentration Pathway 4.5) and high emissions scenario (Representative Concentration Pathway 8.5).
Note: FCS = fragile and conflict-affected states.

Impact of Climate Shocks on Macroeconomic Outcomes and Food Security

Climate shocks hurt FCS economies in the near term and will take a toll on growth and economic development in the longer term, more so than in other countries. In the near term, extreme weather events are found to undermine macroeconomic stability, including through GDP losses, shortfalls in food production, high inflation, and a deterioration of the external position. Over the longer term, worsening drought conditions will erode real GDP per capita growth and exacerbate hunger, which means that incomes in FCS will fall further and further behind other countries.

Near-term Impact of Extreme Weather Events in FCS

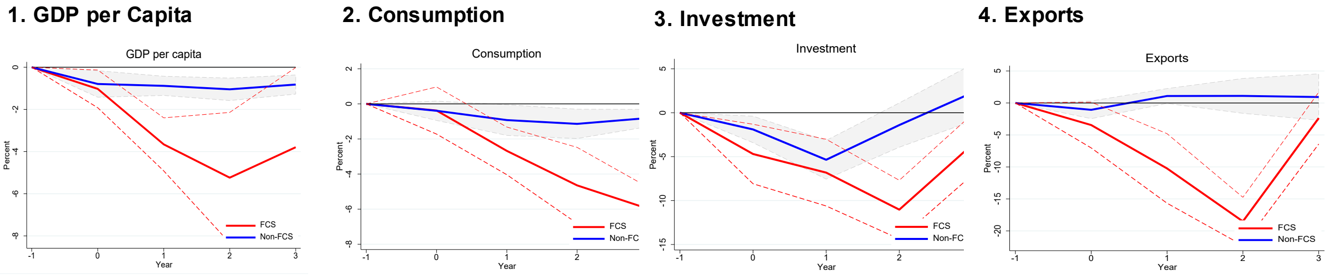
The negative impact of extreme weather events is both larger and more persistent in FCS relative to non-FCS.[8] After three years, cumulative GDP losses reach about 4 percent in FCS, compared to 1 percent in non-FCS (Figure 8, Annex 2).[9] GDP losses could stem from, among others, disruption of economic activity and physical destruction of productive capital and infrastructure, lower productivity in agriculture (damages to crops and livestock), and diversion of resources toward reconstruction (IMF 2020a; Batten 2018). Consumption fails to rebound even after three years, possibly due to lack of social safety nets (IMF 2022b), financial inclusion, and other means of consumption smoothing in FCS. Investment starts to recover after two years in FCS, compared to one year in non-FCS, possibly reflecting slower post-disaster reconstruction amid limited resources and capacity. Extreme weather events also reduce exports and widen the current account deficit. The sharp drop in exports may be related to lack of diversification (for example, reliance on agricultural exports) and weak infrastructure.

---

[8] This section focuses on extreme weather events such as drought, floods, and storms, but not earthquakes or epidemics. A large disaster year is defined by the number of deaths and affected people as a proportion of the country's population. The empirical results are comparable to IMF (2020b) and Duenwald and others (2022).

[9] Further analysis focusing only on low-income countries reveals that FCS still suffer larger losses than non-FCS, though the difference between the two groups is smaller compared with the baseline analysis.

Figure 8. Impact of Extreme Weather Events Conditional on FCS Status


1. GDP per Capita
2. Consumption
3. Investment
4. Exports

Source: Diallo and Lee (forthcoming).

Note: See Annex 2 on methodology. FCS = fragile and conflict-affected states.

Longer-term Effects of Worsening Climate Conditions

Among extreme weather events, droughts significantly impact economic activity in FCS over extended periods. Drought conditions—which are expected to worsen with climate change (UNFCCC 2012; Zaveri, Damania, and Engle 2023)—will create lasting damage to productivity of land, crops, and labor, especially in FCS' predominantly agriculture-dependent economies.[10] Econometric results show that worsening drought conditions—proxied by the declines of the Standardized Precipitation-Evapotranspiration Index (SPEI) from its long-term trend[11]—would have a significant long-term impact on FCS, while no significant long-term impact is found for non-FCS, which means that incomes in FCS would fall further and further behind other countries. Over the longer term, drought conditions in FCS would cut real GDP per capita growth every year by 0.2 percentage point in a low emissions scenario (RCP 2.6) and 0.4 percentage point in a high emissions scenario (RCP 8.5) (Annex 2). By 2060, real GDP per capita in FCS would be 5 percent lower in the high emissions scenario compared to the low emissions scenario.[12] The results show that lower crop productivity, reduced food production, and weaker investment are key channels through which droughts affect long-term growth in FCS. Additional factors that could aggravate the effects of climate change on GDP include a compression of total factor productivity (Hallegatte and Dumas 2009). The effects of changes in the SPEI are not symmetric, as the analysis did not find significant results for the longer-term impact of increases in SPEI levels from its long-term trend, which would be associated with heavy rainfall and, in the extreme, floods and storms. Possible explanations of why rising SPEI levels would not impact long-term growth include that floods and storms may be more localized events and shorter in duration than droughts, reconstruction efforts following floods and storms would offset losses in economic activity, and there are benefits of flooding for recessional agriculture in FCS.

Worsening drought conditions are expected to significantly exacerbate hunger over the longer term. Food production in fragile states is found to be two times more sensitive to drought conditions over the longer term than other countries.[13] Moreover, worsening drought conditions are associated with persistent upward pressure on inflation in FCS, where food represents a large share of consumption.[14] Importantly, the empirical results show that drought conditions increase the share of undernourished population, from an already high level.[15]

---

[10] Droughts will also disrupt other water-dependent sectors such as public water supply, electricity supply, water transportation, mining, and tourism.

[11] The SPEI takes into account both precipitation and potential evapotranspiration in determining drought.

[12] Results are consistent with Kahn and others (2019).

[13] World Bank (2021) finds that in sub-Saharan Africa, which includes many FCS, per capita food production shocks related to droughts and floods have increased from occurring every 12.5 years (average for 1982–2006) to once every 2.5 years (average for 2007–16).

[14] Data from the US Department of Agriculture Economic Research Service show that food represents 42 percent of total consumer expenditure for the median FCS, compared to 23 percent in other countries.

[15] IMF (2020b) finds that in Ethiopia, Malawi, Mali, Niger, and Tanzania, food insecurity increases by 5–20 percentage points with each flood or drought. Hallegatte and others (2016) show that climate change would likely spark higher agricultural prices and could threaten food security in poorer regions such as sub-Saharan Africa and South Asia.

The confluence of lower food production and higher prices in a high emissions scenario would push 2 percentage points more of fragile states' population—about 50 million more people—into hunger by 2060.

Humanitarian and Conflict Impact of Climate Shocks

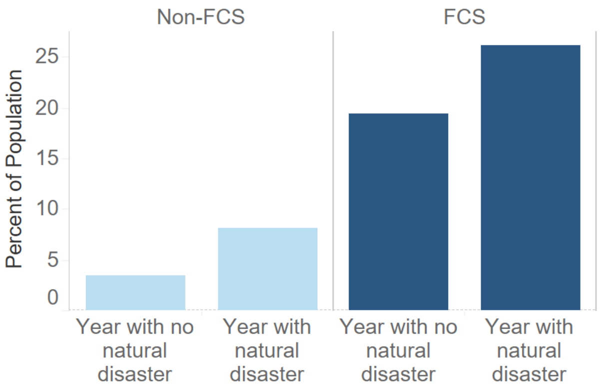
When confronted with climate shocks, fragile states face considerably higher humanitarian casualties. Moreover, where conflict exists, climate shocks exacerbate its intensity, further compounding fragility.

Humanitarian Casualties from Climate Shocks in FCS

Climate shocks lead to significant humanitarian casualties in FCS, including displacement. Centre for Research on the Epidemiology of Disasters, Emergency Events Database data shows that three times as many people in FCS are affected every year by extreme weather events than in other countries. Moreover, following extreme weather events, the share of undernourished population increases significantly in FCS from already high levels (Figure 9). In addition, according to the Internal Displacement Monitoring Centre, close to 10 percent of internal displacement in FCS is directly linked to disasters, with more than twice the share of the population being displaced in FCS than in other countries (Figure 10). More generally, it is important to note that close to 95 percent of refugees, 86 percent of internally displaced people, and 20 percent of migrants globally have originated in FCS countries (Figure 11). While decisions to migrate to other countries are driven by a number of factors, climate change is increasingly a contributing factor (United Nations 2018; Internal Displacement Monitoring Centre 2021; World Development Report 2023).

Figure 9. Prevalence of Undernourishment in Year Following an Extreme Weather Event

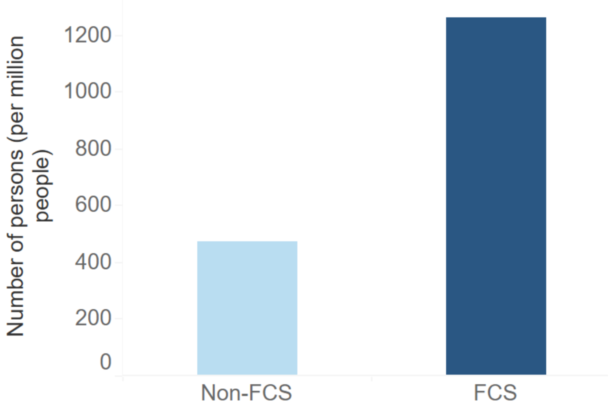
(Percent of population, median across country group)



Sources: Centre for Research on the Epidemiology of Disasters, Emergency Events Database; World Bank, World Development Indicators; and authors' calculations.
Note: FCS = fragile and conflict-affected states.

Figure 10. Disaster Displaced Persons, 2008–22

(Median)

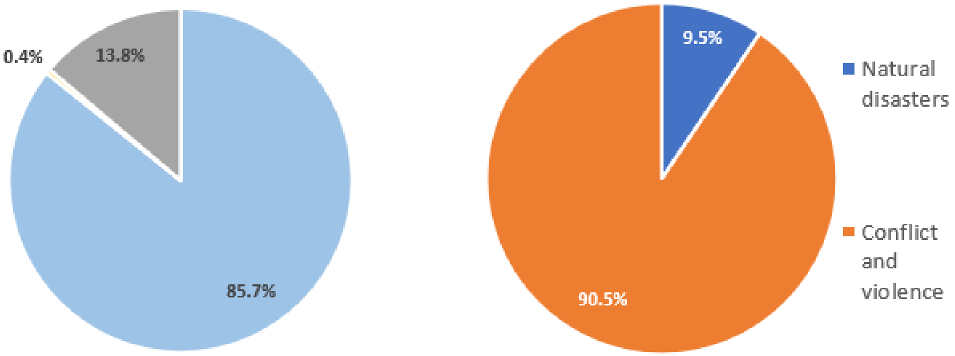


Sources: Internal Displacement Monitoring Centre; and authors' calculations.
Note: FCS = fragile and conflict-affected states.

Figure 11. Forced Displacement and Migration, 2022

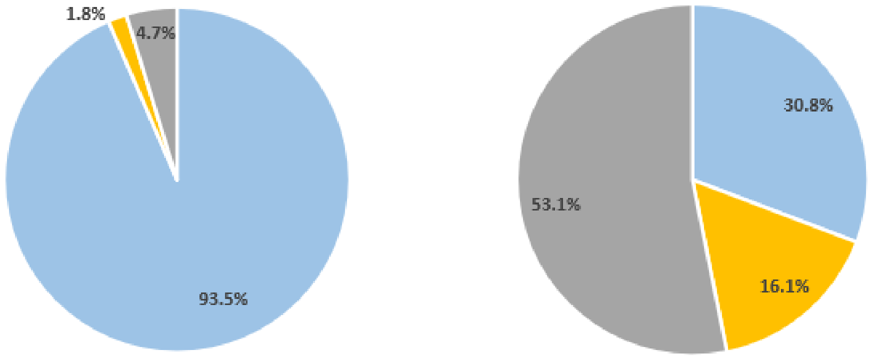
1. Internally displaced people by country group

2. Internally displaced people in FCS by driver



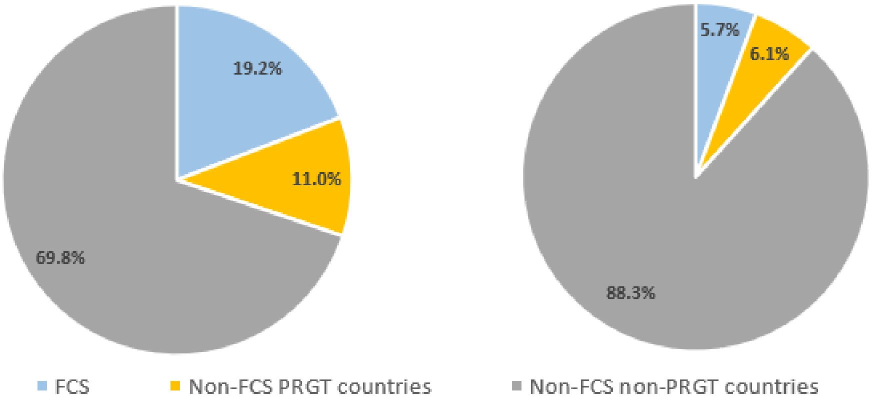
3. Refugees by origin country

4. Refugees by host country



5. Migrants by origin country

6. Migrants by host country



Sources: Internal Displacement Monitoring Centre 2021; International Organization for Migration; UN Refugee Agency; UN Relief and Works Agency; and authors' estimates.

Note: Data on internally displaced people is from Internal Displacement Monitoring Centre (2021); based on this data set, total internally displaced persons in 2022 are estimated at 71.1 million, of which 8.6 million driven by disasters. Data on refugees is from UN Refugee Agency and UN Relief and Works Agency; based on these data sets, total refugees for 2022 are estimated at 32.5 million, of which 26.6 million are under the UN Refugee Agency mandate and 5.9 million under the UN Relief and Works Agency mandate. Data on migrants is based on the International Organization for Migration; based on this data set, total migrants in 2022 are estimated at about 281 million. FCS = fragile and conflict-affected states; PRGT = Poverty Reduction and Growth Trust.

Climate Shocks Raise Conflict Intensity, Exacerbating Fragility

The linkages between climate change and fragility are complex and multifaceted and can lead to intensification of conflict and humanitarian crises. Conflict intensity has been rising across the globe, in particular in FCS countries (Figure 12). The literature identifies several pathways through which climate shocks influence conflict:

Figure 12. Conflict Intensity in Select Countries, 2013–22

(Conflict deaths per million people)

Sources: Uppsala Conflict Data Program; and authors' calculations.
Note: Conflict intensity is constructed based on conflict and population by calculating total fatalities per million people at the country level.
* Denotes country classified as FCS any time between 2013–22.

- **Resource scarcity:** Unequal distribution of resources, unequal vulnerability to climate impacts, and differential access to adaptation measures can exacerbate existing social divisions and contribute to conflicts. Climate change affects the likelihood of intragroup violence via the scarcity of renewable resources such as freshwater, arable land, forests, and fisheries (Koubi 2019). For example, shifts in rainfall patterns and desertification in the Sahel have intensified competition for resources, reinforcing long-existing rivalries and communal violence (Signé and Mbaye 2022; World Bank 2020).

- **Food security:** Changes in climate patterns can negatively impact agricultural productivity, leading to food insecurity, which can cause social unrest and lead to conflict. Harari and la Ferrera (2018) and Johnstone and Mazo (2011) look at this channel for countries in Africa and the Middle East and North Africa region. Baptista and others (2022) find that the intensifying effects of climate change exacerbate food insecurity, reversing years of progress in health and educational achievements in sub-Saharan Africa.

- **Displacement:** Migration arising from climate shocks can lead to increased competition in both host communities and areas of origin, escalating conflict in already strained social and economic systems (Abel and others 2019; Global Center for Adaptation 2022; Reuveny 2007).

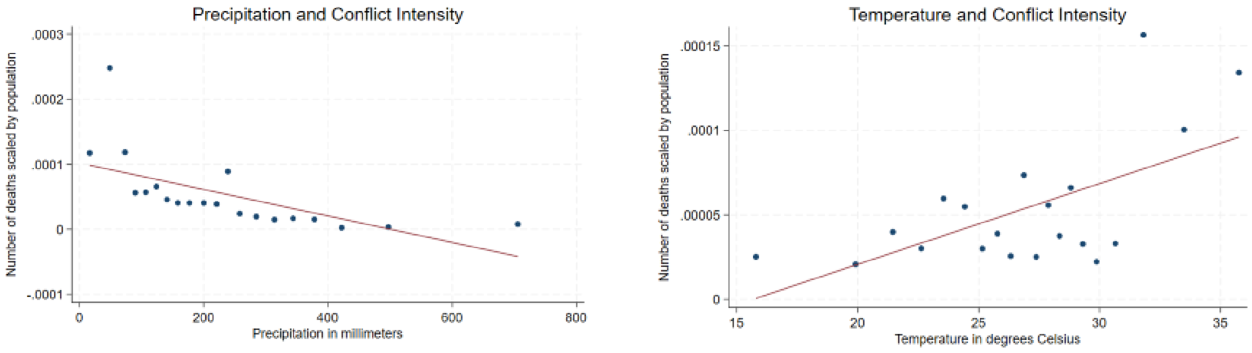
- **Economic shocks:** Climate change can cause significant economic shocks that destabilize countries. For instance, extreme weather events can severely damage infrastructure and reduce economic productivity, leading to unemployment and social unrest. Climate shocks reduce incomes and exacerbate poverty, thus leading to more violence, conflict, and political instability (Burke and others 2009).

Climate shocks raise the intensity of conflict, thereby exacerbating fragility. To overcome severe data challenges in FCS, empirical analysis uses an innovative data set—created by using georeferencing to match weather and conflict data at the regional level on a monthly frequency, for 106 countries over 2013 to 2022—while controlling for economic activity at the regional level (Annex 2). The empirical analysis does not find that climate shocks affect the onset of new conflict, as conflict situations derive from a complex range of factors, such as governance, social dynamics, politics, historical conflicts, and socioeconomic conditions.[16] However, the empirical analysis shows that, where conflict exists, climate shocks exacerbate its intensity (Figure 13). Cross-country panel regressions on a monthly frequency show that a 1 percent increase in temperature is associated with a 0.1 percent increase in conflict intensity (number of conflict-related deaths/population). Annualizing these results show that, in a high emissions scenario and all else equal, by 2060 conflict deaths as a share of the population for a median FCS could increase by 8.5 percent, and up to 14 percent for countries facing an extreme temperature increase.[17] Note that these results underestimate the destructive impact of conflict that does not result in higher deaths.

Figure 13. Climate Shocks and Conflict Intensity

1. Precipitation and Conflict Intensity (binned scatter plot)

2. Temperature and Conflict Intensity (binned scatter plot)



Source: Rehman (forthcoming).

Note: To visualize the 340,842 observations in the data set, the binned scatter plot groups the *x*-axis variable into 20 equal-sized bins (17,042 observations in each bin), computes the mean of the *x*-axis and *y*-axis variables within each bin, and creates a scatter plot of these data points. Conflict intensity is defined as the number of conflict-related deaths as a share of the population.

Climate Vulnerability in Agriculture

A main source of FCS climate vulnerability is their heavy dependence on rainfed agriculture, which is highly sensitive to rainfall, floods, and groundwater. Moreover, the impacts of climate shocks on agriculture are amplified in FCS by conflict, lack of resources, and weak capacity that damage scarce irrigation infrastructure and destabilize agricultural production.

---

[16] While the existing empirical literature does not provide strong evidence that extreme weather events affect the onset of conflict—for instance, no direct relationship was found between drought and civil conflict onset in Africa (Theisen, Holtermann, and Buhaug 2012; Owain and Maslin 2018) or Asia (Wischnath and Buhaug 2014)—studies suggest these disasters can enhance conflict duration, severity, and intensity (Ghimire and Ferreira 2016; Miguel, Satyanath, and Sergenti 2004; Koubi 2019). Furthermore, studies imply that climate-related disasters can heighten political unrest or armed conflict risk if conducive conditions coexist (Ide and others 2020, 2021; Schleussner and others 2016; von Uexkull and others 2016). See also Scartozzi (2021).

[17] Similarly, countries facing an extreme drop in precipitation could see conflict intensity increase of up to 8 percent (Annex 2).

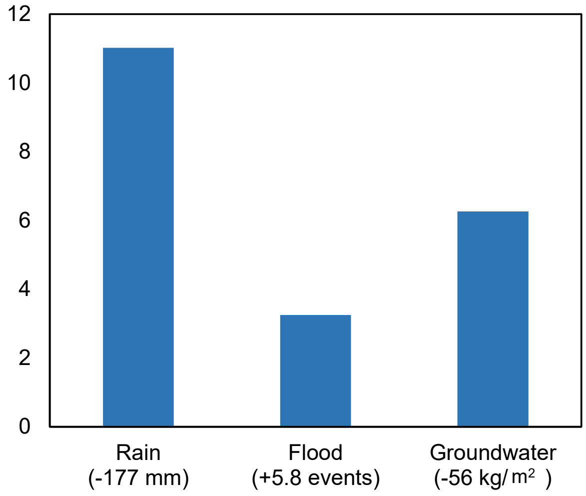
Rainfed Farming Increases Climate Vulnerability of FCS

Agriculture is crucial for FCS economies, but it is highly vulnerable to climate shocks. In 2021, the value added of the agriculture sector represented 22 percent of GDP in FCS, compared to 6 percent in non-FCS. In 2019, 43 percent of employment in FCS was in agriculture, compared to 14 percent for non-FCS. Therefore, shocks to agriculture have broad macroeconomic implications in FCS, including on GDP, exports, employment, household consumption, and government finances. Agriculture is one of the sectors most vulnerable to climate shocks, including because of its heavy water use and sensitivity to variations in temperature and precipitation (Intergovernmental Panel on Climate Change 2022).[18]

Rainfed farming makes agricultural production more vulnerable to climate shocks in FCS. Food and Agriculture Organization of the United Nations AQUASTAT figures suggest that in FCS only 3 percent of cultivated areas are equipped for irrigation, compared to 11 percent in non-FCS. To assess the climate vulnerability of agriculture in FCS, a novel data set is created by using satellite imagery to calculate the "greenness" of farms (Annex Box 2.1)—the density of green on a farmland which serves as a proxy for agriculture production—and to identify rainfed and irrigated farms across 30 FCS over 1984–2021 (Annex 2). Regression analysis shows that farm vegetation in rainfed farms in FCS is significantly affected by volatility in rainfall and groundwater, as well as by the frequency of floods, as opposed to irrigated farms that are not significantly affected. The results suggest that rainfed farms in FCS stand to lose 11 percent of their vegetation when a rainy season disappoints (that is, precipitation falls by one standard deviation), which would become more common place as climate change leads to greater variability of precipitation (Figure 14). The results underscore that lack of irrigation infrastructure and heavy reliance on rainfed farms makes agriculture production and thus the entire economy more vulnerable to climate shocks in FCS.

Figure 14. Estimated Loss of Vegetation on Rainfed Farms in FCS Following a Climate Shock

(Percent of area of rainfed farms)



Source: Koshima (forthcoming).

Note: Brackets show one standard deviation changes in the corresponding climate variables across rainfed farmlands in the data set. FCS = fragile and conflict-affected states.

---

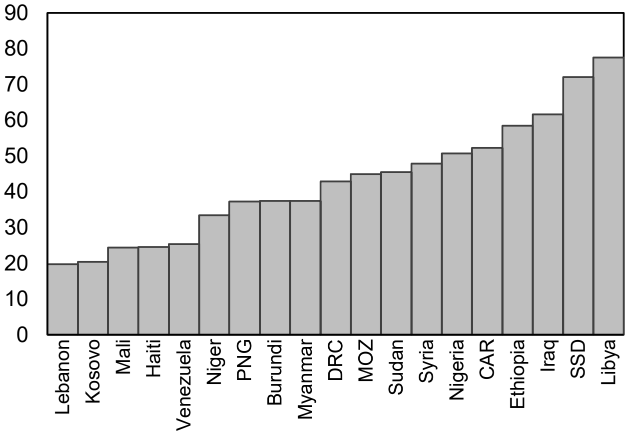
[18] Several studies have found that countries which strongly rely on agriculture are more vulnerable to climate shocks (Kotz, Levermann, and Wenz 2022; Desbureaux and Rodella 2019; Vesco and others 2021). In addition to water dependency, other sources of vulnerability in agriculture in FCS may include low storage capacity (Baptista and others 2022) and heavy reliance on agricultural inputs (oil, seeds, fertilizers).

Fragility Exacerbates Climate Vulnerability of Agriculture in FCS

Even when access to irrigation is available in FCS, many irrigation schemes underperform and significant irrigated farmlands are left unused. Several studies report that a significant portion of irrigation schemes remain unused in developing countries because of lack of maintenance, unsustainable irrigation technologies, wrong crop choices, and poorly designed agricultural policy (Kadigi and others 2019; Bjornlund, Bjornlund, and Van Rooyen 2020). Irrigation inefficiency is a serious problem in FCS. Estimates suggest that 43 percent of area of an irrigated farmland is typically unused for the average of 19 irrigation schemes in FCS (Figure 15).

Figure 15. Unused Areas of Selected Irrigated Farmlands

(Percent of total area of an irrigated scheme)

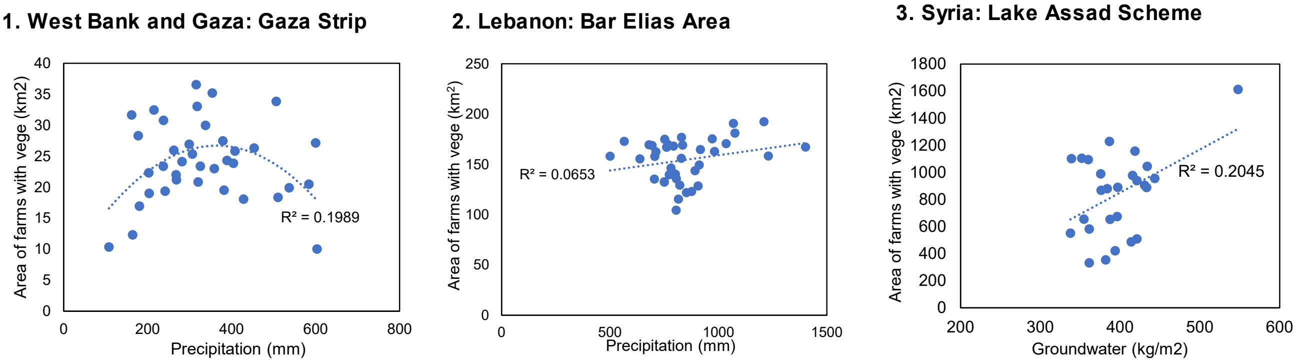


Source: Koshima (forthcoming).

Note: Unused areas of irrigated farmlands are proxied using the difference between the historical peak of farmland with vegetation and the mean level of farmland with vegetation. Data labels in the figure use International Organization for Standardization (ISO) country codes.

Poorly performing irrigation schemes tend to become as vulnerable to climate shocks as rainfed farms. As illustrated by the case of the West Bank and Gaza (Figure 16), rainfed farms tend to show an inverted U-curve where farmland with vegetation tends to drop with little or heavy rainfalls. In contrast, for relatively well-performing irrigation schemes, farmland with vegetation tends to be stable, uncorrelated to rainfall levels, as found in the empirical results discussed previously and illustrated by the case of Lebanon. However, for poorly performing irrigation schemes, farmland with vegetation tends to be highly correlated with climate variables—as illustrated by the Lake Assad scheme in Syria—because malfunctioning infrastructure interrupts the stable water supply and makes farms dependent on unstable rainfall or groundwater.

Figure 16. Farmland with Vegetation, Precipitation, and Local Groundwater Level


1. West Bank and Gaza: Gaza Strip

2. Lebanon: Bar Elias Area

3. Syria: Lake Assad Scheme

Source: Koshima (forthcoming).

Note: vege = vegetation.

Case studies illustrate how different sources of fragility amplify the impact of climate shocks by impairing scarce irrigation infrastructure and destabilizing agricultural production (Figure 17, Annex 3).

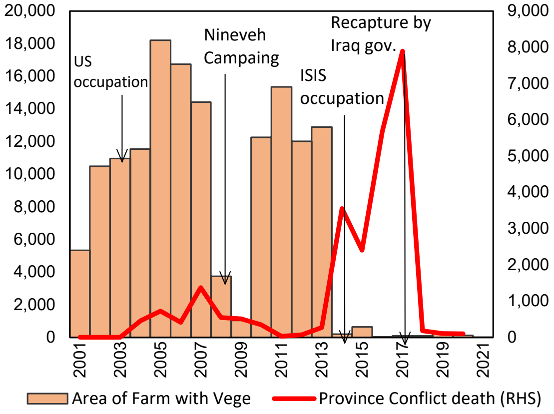
- **Damage and abandonment of irrigation systems by conflict:** Conflicts wreck irrigation systems through the direct impact of battles or the displacement of farmers that impairs their maintenance, increasing the areas' vulnerability to climate shocks. In northern Iraq, the Jazeera irrigation scheme and other vast farmlands almost completely disappeared when the area was occupied by the Islamic State in Iraq and Syria, which actively destroyed irrigation infrastructure in their battles. Mali's largest irrigation scheme (Office du Niger) has been underperforming significantly since the security crisis in 2012. Vegetation losses have been linked to increased flooding (including because of a deterioration of the drainage system), as farmers fled the area due to security risks.

- **Inadequate maintenance because of lack of resources and capacity:** Gravity surface irrigation, which is the most common type of irrigation system in FCS, requires constant maintenance to dredge canals and drainages and repair dikes and pumping equipment. Lack of maintenance seems to be one of the main reasons why irrigation in FCS is severely underperforming and underutilized. In Mozambique, the Limpopo River plain remained highly vulnerable to climate shocks following major floods in 2000. Rehabilitation projects in the 2010s supported by development partners ultimately increased resilience of the area, showing the strong payoff of efforts to recover damaged irrigation infrastructure. In Sudan, the Gezira irrigation scheme, one of the largest in Africa, has been performing poorly mainly due to accumulation of sediment and clogging of canals and pipes. As a result, farmland vegetation in the scheme has become sharply correlated to precipitation, not much different to rainfed farms. As an extreme example, in South Sudan, the Aweil irrigation scheme, one of very few irrigated lands in the country, was abandoned in absence of maintenance, which was last undertaken in the 1980s.
- **Unworkable projects or policies because of poor design, planning, or implementation:** Improperly designed irrigation projects do not reduce climate vulnerability, and ultimately the schemes can become unusable. Improperly designed irrigation systems often have problems of water distribution (over- and underirrigation of parts of fields) and quality (leaching of pollutants). Malfunctioning irrigations cause farmlands to be more sensitive to climate shocks. For example, in Ethiopia, the Lower Awash Plain irrigation scheme was not equipped with proper drainage systems to prevent salinity hazards. An expansion of the project in the late 2000s exacerbated salinity hazards and farmland vegetation became smaller than before the expansion. In Libya, the Great Man-Made River (GMMR) project, which brings water from a large aquifer in the Sahara Desert through thousands of kilometers of pipelines, was unable to provide stable water supply to the irrigation scheme in the Benghazi area and caused it to become more sensitive to local groundwater levels than nearby farms using makeshift wells. Separately, agriculture policies (for instance, land reforms and input subsidies) may aggravate the sensitivity of agriculture to climate shocks if poorly designed and implemented. Chen and others (2017) find that the land reforms in Ethiopia after the 2000s facilitated rentals of farmlands, significantly reduced resource misallocation, and increased productivity—unlike the land policies between the 1970s and 1990s that included abrupt expropriation and frequent redistributions of lands. In Zimbabwe, the Fast-Track Land Reform Program initially damaged agriculture production, although its redesign supported an increase in tobacco production. For input subsidies, studies have found that the effectiveness of the programs depends on coverage and implementation (see, for example, Gignoux and others 2022 on subsidy program introduced in Haiti in 2014; and Theriault, Smale, and Haider 2017 on the fertilizer subsidy program in Burkina Faso).

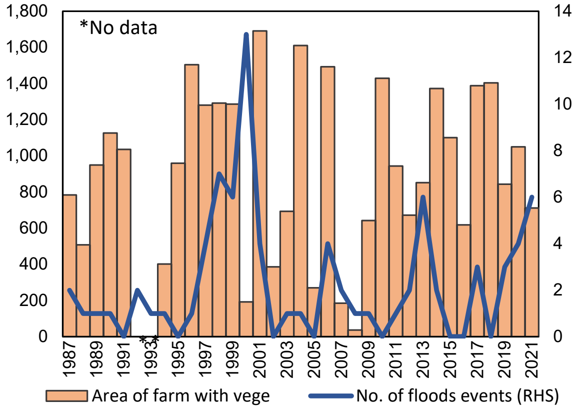
- **Weak oversight and governance over projects:** A country with resource constraints may look to alternative financing schemes (for instance, public-private partnerships or state-owned enterprises [SOEs]) to implement capital-intensive projects. However, several of these schemes in FCS have been plagued by inadequate oversight as well as questions around governance. Palm plantations in the Central African Republic and the Democratic Republic of Congo illustrate that involvement of the private sector or SOEs does not guarantee adequate investment to deliver positive outcomes.

Figure 17. Farmland Vegetation in Selected FCS (km²)

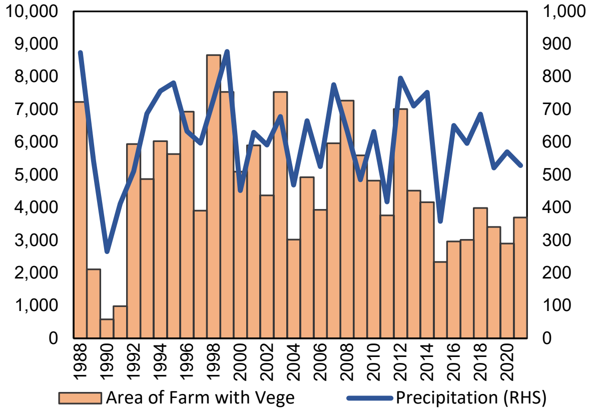
1. Iraq: Nineveh Region



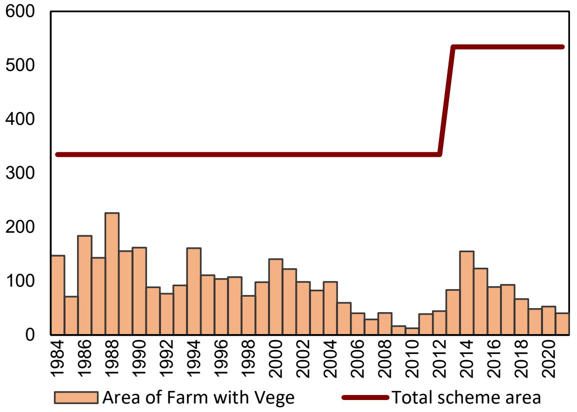
2. Mozambique: Limpopo River Plain



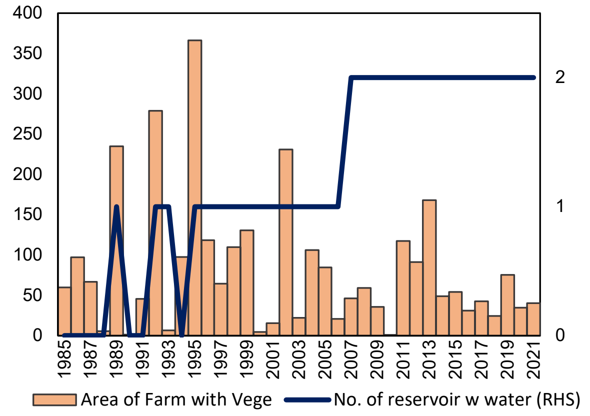
3. Sudan: Gezira Scheme



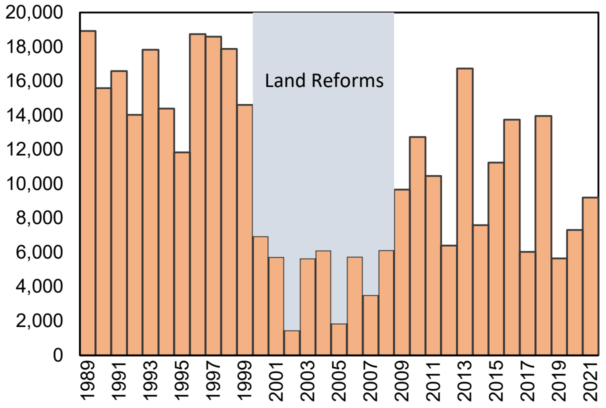
4. Ethiopia: Lower Awash Plain



5. Libya: Great Man-Made River



6. Zimbabwe: Metabeleland North Province



Source: Koshima (forthcoming).
Note: FCS = fragile and conflict-affected states; rhs = right-hand scale; vege = vegetation; no. = number.

Macro-critical Policies for Climate Adaptation in FCS

It is urgent that FCS implement policies for climate adaptation. FCS will need to implement adaptation policies that both facilitate the immediate response to climate shocks and build climate resilience over time. But FCS alone cannot address their immense climate challenges.

Macro-critical interventions can strengthen adaptation efforts in FCS, taking into account the significant heterogeneity across FCS and at subregional levels within FCS. Fragility is complex and complicated. This means that climate adaptation policies need to follow a multidimensional approach that is carefully prioritized and tailored to specific contexts and local communities and that supports conflict prevention and resolution.

Policies to Facilitate Immediate Response to Climate Shocks

- **Build buffers and strengthen institutional capacity to facilitate robust emergency responses.** Empirical evidence shows that countries with larger fiscal buffers—higher fiscal balance and lower public debt—see a faster recovery from extreme weather events (Figure 18, Annex 2).[19] Countries with fiscal space have more scope to respond to disasters, for instance with cash transfers to households and reconstruction spending (Noy 2009; Bayoumi, Quayyum, and Das 2021). It is important to recognize that, in the context of very limited resources, FCS will face difficult trade-offs between building fiscal buffers and investing in other measures to build climate resilience. Having adequate foreign reserves is also associated with a faster recovery from climate-related disasters. It takes three years for FCS with a relatively higher reserves-to-imports ratio to return to predisaster incomes, compared to five years for FCS with a relatively low ratio. While the adequacy of reserves depends on various factors, including the exchange rate regime, the optimal level of reserve coverage is likely to be higher for disaster-prone countries (IMF 2016). In addition to building buffers, other ex ante instruments to facilitate financing of disaster costs are contingent budget lines (that can be reassigned in case of emergency, although these are usually small) and/or prearranged contingent loans (e.g. from international financial institutions that would disburse immediately after disasters. FCS also need to improve spending efficiency and strengthen public investment management (Aydin and others 2022). More generally, macroeconomic policies should be supported by frameworks, including a medium-term fiscal framework, that reflect adaptation policies and climate risk mitigation and preparedness (Duenwald and others 2022; IMF 2016).

- **Strengthen the social safety net to protect the most vulnerable.** Against a backdrop of high informality and poverty rates, a stronger social safety net in FCS would help vulnerable households cope with climate shocks. Social safety nets in FCS requires well-targeted programs with efficient delivery systems that can be scaled up rapidly when a disaster strikes, and also wound down once the emergency subsides.

- **Transfer disaster risk through sovereign insurance, where this is cost-effective.** Most FCS are unable to adequately self-insure against disasters, especially larger ones, by building policy buffers and resilient infrastructure. In this context, risk transfer through sovereign insurance is an important tool for financing disaster risks.[20] Fragile states should seek to transfer risk to regional insurance pools (where these exist), as these facilities are more affordable than market insurance due to risk pooling and most provide protection against extreme climate-related disasters such as droughts and floods. Regional facilities have been set up with World Bank assistance in the Caribbean, Africa, the Pacific, and Southeast Asia, and several fragile states are insured members (Burkina Faso, Mali, the Marshall Islands, Niger) or eligible members (Chad, Ethiopia, Micronesia, Papua New Guinea, Solomon Islands, Timor-Leste, Tuvalu, Zimbabwe). The level of insurance,

---

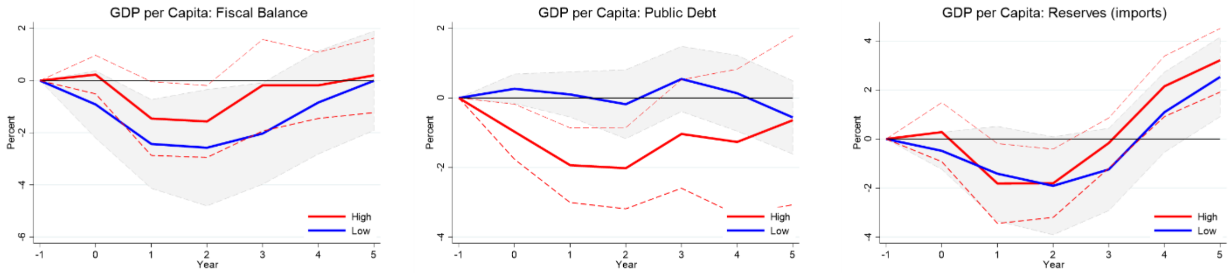
[19] Additional results show that these policy buffers are more important for FCS than non-FCS (see Annex 3). Findings for FCS are in line with studies for other economies and regions (IMF 2017). See also IMF (2022e, 2022f) for the application of the IMF's DIGNAD model to assess the macroeconomic impacts of extreme weather events in some small island FCS.

[20] The World Bank's multilayer risk approach determines the most cost-efficient way of combining instruments to achieve a predetermined coverage level. Instruments are prioritized in terms of cost and timeliness of disbursement, usually deploying self-insurance for smaller and more frequent disasters, followed by contingent credit lines, insurance, and finally catastrophe bonds for the most infrequent/severe disasters (Ghesquiere and Mahul 2010).

however, remains small due to cost, and donor grants could help achieve a more optimal level of protection, as discussed in the following (Cebotari and Youssef 2020).

Figure 18. Selected Policy Buffers and Impact of Extreme Weather Events on GDP per Capita

1. Fiscal Balance **2. Public Debt** **3. Foreign Reserves**



Source: Diallo and Lee (forthcoming).
Note: The sample covers all countries classified as FCS at least once during FY2006–FY22. “High” (red line) refers to countries above the median, and “low” (blue line) refers to countries below the median of the distribution of the policy variable. See Annex 2. FCS = fragile and conflict-affected states.

Policies to Build Climate Resilience Over Time

- **Embed climate-resilience into efforts to improve peace and security.** Poorly designed climate interventions can compound existing inequalities and exacerbate conflict risk instead of improving resilience to external shocks (Cappelli and others 2023). At the same time, security efforts that do not take into account climate adaptation would miss addressing underlying threats that worsen social tensions and feed into conflict (Global Center for Adaptation 2022). In this regard, for example, the African Union is placing emphasis on the importance of comprehensively assessing the climate, peace, and security nexus, and consequently to link early warning systems and adaptation measures with violent conflict prevention (African Union 2022).

- **Improve governance and fight corruption, including to facilitate access to financing.** The empirical results confirm that countries with weak governance see a more severe impact of drought on long-term growth. Compared to FCS with above average control of corruption, FCS with below average control of corruption would see lower real GDP per capita growth every year by about 0.2 percentage point in a low emissions scenario (RCP 2.6) and 0.4 percentage point in a high emissions scenario (RCP 8.5). The costs of corruption in the climate change context come from misdirected and poor-quality investments (as illustrated by the case studies), slow and inadequate responses to extreme weather events, and the loss and misuse of revenues desperately needed to build climate resilience. Corruption also makes it easier to evade rules and regulations, which can result in environmental damage and resource overuse. Climate adaptation policies will have winners and losers, and coordination between government and the private sector is required. Improving transparency and accountability can help build citizen trust in government and in the legitimacy of climate-related policy decisions (World Bank 2022). Relevant areas to tackle corruption include fiscal governance, rule of law, and market regulation, among others (IMF 2018). Upgrading governance frameworks to enhance control, monitoring, and transparency of climate-related policies can reduce the perceptions of corruption and can broaden the opportunity for access to climate financing. Moreover, some studies have identified poor governance and institutional instability as important factors in the relationship between resource scarcity and conflict (Barnett and Adger 2007; Bueno de Mesquita and Smith 2017). In this context, better governance could play an important role in mitigating climate-induced conflict risks and displacement (Adger and others 2014).

- **Develop climate-smart agriculture to build resilience in agriculture production and reduce food insecurity.** The empirical results show that countries with higher agricultural investment are less affected by disasters, including because better irrigation systems reduce vulnerability to droughts and floods, as discussed earlier (Annex 2). Investing in climate-smart agricultural practices and technologies can enhance resilience to climate shocks (Food and Agriculture Organization of the United Nations 2021). This includes improving irrigation, drainage systems, and water management. The use of fertilizer and insecticide, machinery, anti-erosion measures, and improved seeds and livestock can increase productivity and help withstand adverse climate conditions (IMF 2020b). Establishing early warning systems and broadening mobile phone availability in rural areas can help raise farmers' awareness and address information asymmetries on food prices and weather.

- **Scale up social spending and climate-resilient infrastructure investments that are carefully designed and implemented.** Regression results show that higher social spending helps mitigate the adverse impact of climate change on growth (Annex 2). Protecting a country's human capital through continued access to quality health and education programs is indispensable for fragile countries to promote inclusive growth and poverty reduction. FCS also need more and high-quality climate resilient infrastructure, while enhancing infrastructure governance and institutional quality. To keep adaptation investment affordable and facilitate a careful prioritization of projects, it is crucial to monitor asset conditions and ensure efficient selection, execution, and maintenance of investment projects, based on credible cost-benefit analyses (Aligishiev, Massetti, and Bellon 2022).[21] This includes incorporating climate financing throughout the budgeting process, ensuring transparent procurement, and implementing pertinent risk management. Noting FCS capacity constraints, all these efforts may need to be relatively basic at first.

- **Enhance financial inclusion to encourage private investment and enable households to smoothen shocks.** Financial inclusion is crucial for the private sector to cope with climate risks, including to promote climate-resilient investment and employment. Access to safe liquid savings accounts, emergency borrowing, and insurance is crucial for households and firms to withstand climate shocks. Financial markets in many FCS are underdeveloped and financial inclusion is inadequate. Reforms should focus on enhancing financial stability and developing well-functioning financial markets to provide adequate instruments (IMF 2021). In FCS where mobile money plays an important role, broadening mobile phone availability while strengthening supervision of mobile money operations would also help improve financial inclusion.

Urgent Need for International Support

Sizable and sustained support from development partners for climate adaptation financing in FCS is urgent to avoid worse outcomes. FCS need both external financing and technical assistance to strengthen their capacity to absorb and spend climate finance effectively.

The financing needed for climate adaptation is well beyond what FCS countries can afford on their own. Based on estimates by Aligishiev, Massetti, and Bellon (2022), adaptation costs for FCS are about 1.5 percent of GDP per year, compared to 1 percent of GDP in other countries, which corresponds to 13 percent of tax revenues in FCS compared to less than 6 percent in other countries—however, there is a wide range of adaptation cost estimates due to differing assumptions (see, for instance, UN Environment Programme 2021). Moreover, financing to address adaptation needs comes on top of the already large financing needed to make substantial progress toward the Sustainable Development Goals, which are critical to mitigate and escape fragility. Thus, while domestic revenue mobilization and reprioritization of spending will need to play a role, multilateral and bilateral financing (grants and concessional financing) will be essential to help FCS adapt to climate change.

Sizable and sustained concessional financing from development partners for climate adaptation in FCS is urgent to avoid worse outcomes. The international community must help FCS as a global public good, or else spillover effects associated with fragility and conflict could become even more disruptive, including more forced displacement and migration to other countries. Financing climate adaptation can be less costly than

---

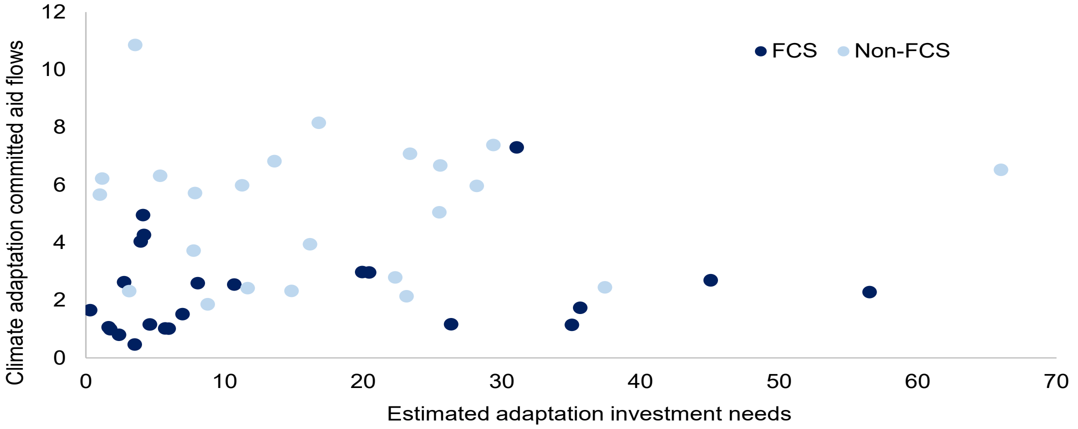
[21] Efforts to enhance climate-resilient infrastructure will also need to consider broadening access to electricity (including from renewable sources) (IMF 2020b) and improving land use regulations and zoning.

frequent disaster and humanitarian relief, but so far has fallen short of needs. According to the International Federation of Red Cross and Red Crescent Societies (2019), meeting humanitarian needs following climate-related disasters costs international funders US$3.5 to US$12 billion per year, which could balloon to US$20 billion per year by 2030.[22] These estimates do not include costs related to refugees and migrants in host countries. Aid Atlas puts climate adaptation aid flow commitments to FCS at about US$30 billion cumulative between 2010 and 2020, well short of the estimated needs (Figure 19). Financial support should be provided in the form of grants and concessional financing to avoid creating pressures on fiscal sustainability.

Facilitating access to global climate funds can help. The World Bank's Scaling Adaptation Finance in Fragile Environments activity points to several barriers to scaling climate finance in FCS countries, among others: (1) limited political will among donors to promote longer-term climate actions, with priority often focused on supporting emergency and humanitarian interventions; (2) inadequate technical capacity and resources in FCS to navigate the complex landscape of different funding mechanisms; and (3) security concerns that threaten project delivery. Belianska and others (2022) also find that varying requirements and criteria across climate funds creates bottlenecks. FCS need to develop well-defined climate strategies, with a set of credible, "bankable" projects, that are linked with the country's development strategy and macroeconomic framework, and can be supported by international partners (IMF 2019, 2023; Fouad and others 2021). Improvements in the quality and availability of data will also be needed. At the same time, it will be important for climate finance funds and initiatives to provide FCS-focused technical support facilities, dedicated funding windows, and application criteria tailored to the FCS context.

Support from international partners for strengthening sovereign disaster risk insurance can help leverage limited donor funds while facilitating the needed ex post financing. This can be done indirectly, through the recapitalization of regional pools, which would help lower their reinsurance costs, increase the coverage limits given more risk-taking capacity, and lower insurance premia for sovereigns (Cebotari and Youssef 2020). Support can also be provided directly through temporary subsidization of premiums (for example, to encourage eligible countries to join regional insurance pools—in turn helping further reduce insurance premiums through increased pooling).

Figure 19. Climate Adaptation Investment Needs and Committed Aid Flows
(US dollars per capita, annual average)



Sources: Aid Atlas; Aligishiev, Massetti, and Bellon (2022); and authors' estimates.
Note: Estimated adaptation investment needs are from Aligishiev, Massetti, and Bellon (2022) for 23 FCS and 29 non-FCS. Climate adaptation committed aid flows are from Aid Atlas, with the annual average estimated from the cumulative flows between 2010–20. FCS = fragile and conflict-affected states.

---

[22] Total humanitarian aid from Organisation for Economic Co-operation and Development countries reached US$25 billion in 2021, of which an estimated 80 percent was directed to FCS.

On top of financing, FCS need technical assistance and training from development partners to strengthen capacity to absorb and spend climate finance effectively. As illustrated by the case studies, climate-related policies and investments will only succeed if they are adequately designed and implemented. FCS will need extensive capacity development support from partners—that draws on successful cases and best practices—to design and implement their climate adaptation strategies and projects. Capacity development support will need to take into account the opportunities, capacity constraints, and governance challenges in an FCS setting.

The IMF is stepping up support to FCS in dealing with climate challenges through carefully tailored policy advice, financial assistance, and capacity development. The IMF's FCS Strategy (IMF 2022a) promotes a deeper understanding of the drivers of fragility, tailoring of program design, integration of capacity development support, and synergies with partners. Drawing on these insights, the IMF advises FCS on reforms to build climate resilience. The IMF has also enhanced its financial support for climate action through the standard facilities, emergency financing, and the new Resilience and Sustainability Facility (RSF). IMF technical assistance and training—particularly on fiscal, financial, statistics, governance, and macroeconomic frameworks—can help FCS upgrade climate-related skills and better manage risks. IMF capacity development can also help countries meet public finance management–related and governance requirements needed to access climate financing.

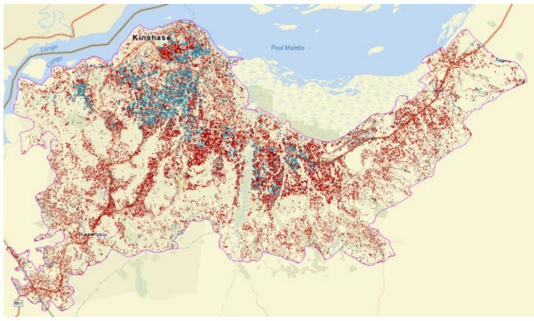
The IMF's new RSF is an important new financing instrument that can help FCS address climate change challenges and catalyze climate finance. As of July 5, 2023, nine RSF-supported programs have been approved, including for two FCS (Kosovo, Niger). While the design of IMF-supported programs is tailored to country circumstances, examples of RSF reforms include measures to strengthen monitoring of climate-related spending, integrate climate risks into fiscal planning, incorporate climate-related issues into public investment management, and strengthen climate-related risk management for financial institutions (IMF 2022c). When designing RSF-supported programs for FCS, analyses in this note underscore the importance of incorporating an assessment of the underlying climate vulnerability-fragility links, identifying fiscal policies that help countries respond efficiently to climate events, strengthening the governance frameworks to increase the efficacy of the climate adaptation tools, as well as backing reform implementation with comprehensive capacity development support from the IMF and other international partners.

Box 1. Urbanization and Increased Flood Risks in Kinshasa, Democratic Republic of the Congo

Kinshasa is a fast-growing capital city of the Democratic Republic of the Congo and is exposed to high flood risks. World Bank (2019) estimates that the population of Kinshasa has increased 30-fold between 1960 and 2017, and around 65 percent of urban population falls below the poverty line. This expansion has been driven by inflows of rural population, including those displaced by conflict (World Bank 2018). Kinshasa is in the Congo Basin where heavy rainfall supports one of the largest rainforests in the world. Between 2001 and 2021, the highest daily precipitation in Kinshasa reached 158 millimeters, and there was an 80 percent chance of occurrence of daily precipitation exceeding 99 millimeters in any given year. This heavy rainfall frequently caused flash floods in the Nd’jili River and other tributaries, which run through the city and flow into the Congo River.

Kinshasa has expanded without urban planning or adequate infrastructure (World Bank 2019). Based on readings from satellite imagery,[1] it is estimated that in 1994, the densely developed area of Kinshasa was limited to 21 square kilometers, located mostly in the city center, which by 2022 had expanded to 100 square kilometers, sprawling all over the outskirts of the city (Box Figure 1.1).

Box Figure 1.1. Map of the Densely Developed Area in Kinshasa

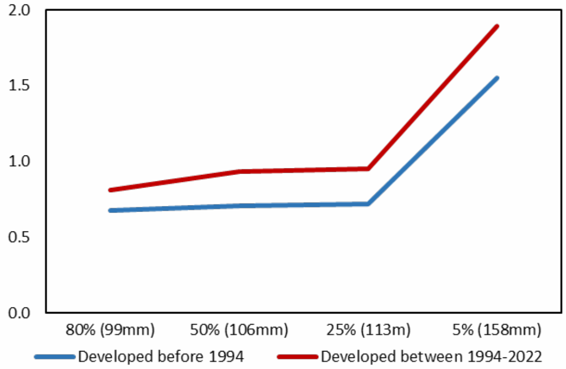


Source: Koshima (forthcoming).
Note: Blue denotes areas developed before 1994, and red denotes areas developed between 1994–2022.

The unplanned expansion of the densely developed area has increased the flood risks in Kinshasa. Flood simulations were undertaken to examine flood risks in the area developed before and after 1994.[2] The results show that a greater percentage of the area developed after 1994 will experience deadly inundation (exceeding two meters deep) than the area developed before 1994 (Box Figure 1.2). The increased flood risks arise from more population living in the floodways of Nd’jili River and other tributaries. With 158 millimeters of daily rainfall (which has a 5 percent probability of occurring every year), the number of people exposed to life-threatening flood risks in these areas is estimated at 62,000 in 2022, compared to 9,000 in 1994.[3]

Box Figure 1.2. Kinshasa: Deeply Inundated Area by Flood Simulation

(Percent of densely developed area)



Source: Koshima (forthcoming).

---

[1] This uses a map of Normalized Difference Built-up Index (NDBI). The geospatial analysis procedure is similar to that for a map of Normalized Difference Vegetation Index, except that a map of NDBI combines short-wave infrared and near-infrared imageries of Landsat. Because built-up structures, such as buildings, reflect more short-wave infrared and less near-infrared, a map of NDBI can distinguish, for example, densely developed urban areas from lightly developed areas and agricultural lands.

[2] The simulation is based on the HEC-RAS software, which is widely used for flood analysis. Area of inundation is estimated through 24-hour simulation with the following scenarios of historically observed rainfalls in Kinshasa: 4.11 millimeters/hour (99 millimeters/day with 80 percent chance in any given year), 4.41 millimeters/hour (106 millimeters/day with 50 percent chance), 4.70 millimeters/hour (113 millimeters/day with 25 percent chance), and 6.60 millimeters/hour (158 millimeters/day with 5 percent chance).

[3] This assumes population density of 28,000 people per square kilometer based on World Bank (2019).

Annex 1. Definition of Fragile and Conflict-Affected States (FCS)

For this note, the definition of FCS is based on the World Bank Classification of Fragile and Conflict-Affected Situations from FY2006 to FY2024.[23] The IMF adopted the methodology, thresholds, and criteria of the World Bank's FCS list as part of the FCS strategy approved in 2022. A total of 61 countries have been classified as FCS at least once, of which 17 countries have been considered FCS throughout the sample period. As of FY2024, 39 countries are classified as FCS. Country coverage differs across the different empirical analyses in the note due to the focus and data availability for each section.

---

[23] These can be found at https://www.worldbank.org/en/topic/fragilityconflictviolence/brief/harmonized-list-of-fragile-situations.

Annex Table 1.1. List of Fragile and Conflict-Affected States, FY2006–FY24

Country	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	Total
Afghanistan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Angola	1	1	1	1	1	1	1	1												8
Armenia																	1			1
Azerbaijan																	1			1
Bosnia and Herzegovina					1	1	1	1	1	1	1									7
Burkina Faso															1	1	1	1	1	5
Burundi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Cambodia	1	1	1	1																4
Cameroon				1	1										1	1	1	1	1	7
Central African Republic	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Chad	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Comoros	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Congo, Democratic Republic of	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Congo, Republic of	1	1	1	1	1	1	1	1	1				1	1	1	1	1	1	1	16
Cote d'Ivoire	1	1	1	1	1	1	1	1	1	1	1	1	1	1						14
Djibouti	1	1	1	1	1							1	1	1						8
Eritrea	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Ethiopia																	1	1	1	3
Gambia, The	1	1	1	1	1						1	1	1	1	1	1				11
Georgia					1	1	1													3
Guinea	1	1	1	1	1	1	1	1												8
Guinea-Bissau	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Haiti	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Iraq				1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
Kiribati			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	16
Kosovo	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Lao PDR	1	1	1	1												1				5
Lebanon											1	1	1	1	1	1	1	1	1	9
Liberia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				16
Libya								1	1	1	1	1	1	1	1	1	1	1	1	12
Madagascar									1	1	1	1								4
Malawi									1											1
Mali									1	1	1	1	1	1	1	1	1	1	1	11
Marshall Islands							1	1	1	1	1	1	1	1	1	1	1	1	1	13
Mauritania		1																		1
Micronesia, Federated States of							1	1	1	1	1	1	1	1	1	1	1	1	1	13
Mozambique													1	1		1	1	1	1	6
Myanmar	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Nepal					1	1	1	1	1											5
Niger															1	1	1	1	1	5
Nigeria	1	1													1	1	1	1	1	7
Papua New Guinea	1	1	1		1							1	1	1	1	1	1	1	1	12
Sao Tome and Principe	1	1	1	1	1	1													1	7
Sierra Leone	1	1	1	1	1	1	1	1	1	1	1	1	1							13
Solomon Islands	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Somalia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
South Sudan								1	1	1	1	1	1	1	1	1	1	1	1	12
Sudan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Syrian Arab Republic								1	1	1	1	1	1	1	1	1	1	1	1	12
Tajikistan	1			1	1	1														4
Timor-Leste	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	17
Togo	1	1	1	1	1	1	1	1	1	1	1	1	1	1						14
Tonga	1	1	1	1	1															5
Tuvalu								1	1	1	1	1	1	1	1	1	1	1	1	12
Ukraine																		1	1	2
Uzbekistan	1	1	1	1																4
Vanuatu	1	1	1																	3
Venezuela, RB															1	1	1	1	1	5
West Bank and Gaza	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Yemen, Republic of				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
Zimbabwe	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
Grand Total	**35**	**35**	**34**	**36**	**36**	**32**	**32**	**35**	**36**	**33**	**35**	**35**	**36**	**36**	**37**	**39**	**39**	**37**	**39**	

Source: World Bank Classification of Fragile and Conflict-Affected Situations.

Annex Table 1.2. Typology of Fragile and Conflict-Affected States, FY2020–FY2024

	Conflict	Instituational and Social Fragility	FCS prior to FY2020
Low income	Afghanistan*	Burundi*	Guinea
	Burkina Faso	Chad*	Madagascar
	Central African Republic*	Eritrea*	Malawi
	Congo, Dem. Rep.*	Gambia, The	Sierra Leone
	Ethiopia	Guinea-Bissau*	Tajikistan
	Mali	Haiti*	Togo
	Mozambique	Liberia	
	Niger		
	Somalia*		
	South Sudan*		
	Sudan*		
	Syrian Arab Republic		
	Yemen, Rep.		
Lower middle income	Cameroon	Comoros*	Angola
	Myanmar*	Congo, Rep.	Cambodia
	Nigeria	Kiribati	Cote d'Ivoire
		Lao PDR	Djibouti
		Micronesia, Fed. Sts.	Mauritania
		Papua New Guinea	Nepal
		São Tomé and Príncipe	Uzbekistan
		Solomon Islands*	Vanuatu
		Timor-Leste	
		Zimbabwe*	
Upper middle income	Armenia	Kosovo*	Bosnia and Herzegovina
	Azerbaijan	Lebanon	Georgia
	Iraq	Libya	Tonga
	Ukraine	Marshall Islands	
	West Bank and Gaza*	Tuvalu	
		Venezuela, RB	

Source: World Bank Classification of Fragile and Conflict-Affected Situations.
Note: To illustrate the differentiated nature of fragility and conflict, countries are separated in the following categories: (1) countries with high levels of institutional and social fragility and (2) countries affected by violent conflict. This distinction was introduced in the FY2020 list, and the classification is therefore not available prior to FY2020. Countries whose classification changed during FY2020–FY2024 are shown by the latest classification. Countries classified as FCS throughout the sample period are marked with asterisk. FCS = fragile and conflict-affected states.

Annex 2. Data and Empirical Approaches

This annex details data and models used in the empirical analysis throughout this note.[24]

Near-term Macroeconomic Impact of Extreme Weather Events

Jorda's local projection method is employed to estimate the response of macroeconomic variables to extreme weather events, as discussed in the section titled "Impact of Climate Shocks on Macroeconomic Outcomes and Food Security." The model specification is as follows:

$$y_{i,t+h} - y_{i,t-1} = \alpha_i^h + \beta_1^h\, shock_{i,t} + \beta_2^h \left(shock_{i,t} * FCS_{i,t}\right) + \theta M_{i,t} + \gamma_t^h + \varepsilon_{i,t+h}$$

where $y_{i,t}$ is log of the variable of interest (for example, GDP per capita), $shock$ is a dummy variable for the extreme weather event, FCS is the dummy variable indicating FCS classification, and $M_{i,t}$ is a set of control variables, including lags of the dependent variable and lags of the climate shock. α_i^h and γ_t^h are country and time fixed effects, respectively. The equation is estimated for each $h = 0, \ \ldots, \ 3$, where $h = 0$ is the year of the shock. Variable definitions and sources are in Annex Table 2.1.

In defining the climate disaster shock, the focus lies on studying the impact of experiencing a disruptive year (rather than event) to capture both the effect of rare large-scale events and frequent smaller-scale events. Data on extreme weather events come from the Centre for Research on the Epidemiology of Disasters, Emergency Events Database. Only climate-related disasters are selected, including drought, flood, and storm, but not earthquakes or epidemics. The dummy takes a value of "1" when a country's annual death plus 0.3 times the number of affected people exceeds 0.01 percent of its population and "0" otherwise. Though some studies have used reported damages, the data coverage for this indicator is relatively weak for FCS.

The sample covers all countries excluding advanced economies and small states (with population below 1 million) for the period 2004–20, in line with the timeframe for which FCS classification is available. Note that FY2006 FCS classification is assessed on 2004 data, and a similar two-year difference for other fiscal years.

The results show the impact of extreme weather events on the level of per capita GDP through consumption, investment, and trade channels. Drought, floods, and storms have heterogenous impacts (Annex Figure 2.1). Much of the near-term GDP contraction is driven by floods and storms, with storms having a large immediate impact on investment. Floods have a deflationary impact. In contrast, droughts adversely affect food production and push up inflation, increasing the prevalence of undernourishment. Our results are robust to including different levels of lag values of the dependent variable or shock variable as control variables in the regression, and are broadly in line with other findings in the literature (IMF 2020a; Duenwald and others 2022; Kabundi, Mlachila, and Yao 2022).

The second part of the analysis, shown in the section titled "Macro-critical Policies for Climate Adaptation in FCS," focuses on how policy buffers mitigate the near-term impact of extreme weather events in FCS. Here the sample is restricted to countries that were classified as FCS at least once between FY2006 and FY2022, and the sample is extended to 1980–2020 for these countries. With the use of interaction terms, the analysis estimates the impact of climate shocks conditional on policy buffers over a five-year horizon. The results are shown by countries above or below the median of the distribution of the policy variable. The model specification is as follows:

$$y_{i,t+h} - y_{i,t-1} = \alpha_i^h + \beta_1^h\, shock_{i,t} + \beta_2^h \left(shock_{i,t} * policy_i\right) + \theta M_{i,t} + \gamma_t^h + \varepsilon_{i,t+h}$$

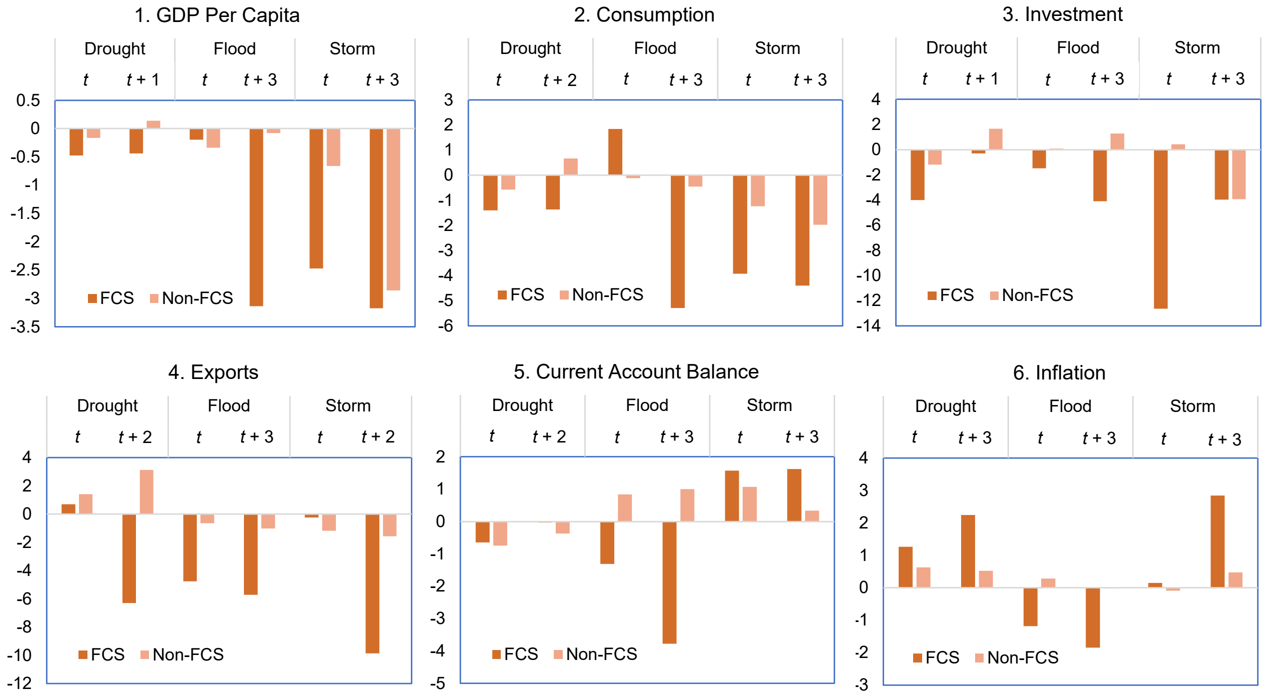
---

[24] Estimates are subject to significant model and coefficient uncertainty due to the need for parsimonious models and the presence of wide confidence bands.

The results show that fiscal buffers—as measured by a higher fiscal balance and lower public debt—are associated with a faster recovery (Annex Table 2.2). External buffers—as measured by foreign reserves in months of imports—also matter. Additional results show that these policy buffers are more important for FCS than non-FCS (Diallo and Lee, forthcoming). For instance, since FCS have limited access to financial markets, mobilizing domestic resources swiftly is more crucial to absorb shocks. Moreover, high debt seems to be more detrimental given their low debt-carrying capacity. Our findings are broadly in line with the literature (IMF 2017, 2020b; Bayoumi, Quayyum, and Das 2021).

Annex Figure 2.1. Near-term Macroeconomic Impacts of Extreme Weather Events Disasters

(Percent change compared with predisaster year; year t = disaster year)



Source: Diallo and Lee (forthcoming).
Note: FCS = fragile and conflict-affected states.

Annex Table 2.1. Variable Definitions and Sources for Near-term Analysis

Variables	Definition (source)	Median of the Total Sample	Median of “High” Group	Median of “Low” Group
Primary fiscal balance	Overall balance excluding net interest payment, percent of GDP (IMF WEO)	–2.3	–0.1	–4.7
Public debt	General government gross debt, percent of GDP (IMF WEO)	40.7	70.9	25.2
Agricultural investment	Agricultural expenditures, percent of agricultural GDP (FAOSTAT)	3.5	6.8	1.6
Foreign reserves	Foreign exchange reserves, in months of imports (IMF IFS)	3.2	5.4	1.6
Trade openness	Size of exports and imports in relation to GDP (WDI)	62.7	91.4	45.0

Source: Diallo and Lee (forthcoming).
Note: IFS = International Financial Statistics database; WDI = World Development Indicators; WEO = World Economic Outlook database.

Annex Table 2.2. Near-term Impact of Extreme Weather Events on GDP per Capita: Role of Policy Buffers

	(1)	(2)	(3)	(4)
Fiscal Balance	*t0*	*t* + 1	*t* + 2	*t* + 3
Disaster	-1.069	-2.509	-2.678	-2.289
	(0.766)	(1.059)	(1.539)	(1.455)
Disaster#Policy	1.235	1.130	1.095	2.073
	(0.734)	(0.792)	(0.899)	(1.228)
Observations	743	697	652	605
Number of groups	47	47	47	47

	(1)	(2)	(3)	(4)
Trade Openness	*t0*	*t* + 1	*t* + 2	*t* + 3
Disaster	-0.891	-1.665	-2.412	-2.279
	(0.370)	(1.006)	(1.500)	(1.435)
Disaster#Policy	0.426	-0.320	0.268	1.821
	(0.274)	(0.552)	(0.530)	(0.577)
Observations	613	613	580	541
Number of groups	43	43	43	43

	(1)	(2)	(3)	(4)
Public Debt	*t0*	*t* + 1	*t* + 2	*t* + 3
Disaster	0.279	0.156	0.0967	0.861
	(0.240)	(0.399)	(0.739)	(0.669)
Disaster#Policy	-1.427	-2.130	-2.583	-2.557
	(0.681)	(0.562)	(0.534)	(0.724)
Observations	724	680	637	592
Number of groups	45	45	45	45

	(1)	(2)	(3)	(4)
Reserves (Imports)	*t0*	*t* + 1	*t* + 2	*t* + 3
Disaster	-0.482	-1.417	-1.912	-1.242
	(0.460)	(1.174)	(1.215)	(1.022)
Disaster#Policy	0.765	-0.400	0.105	1.079
	(0.849)	(0.742)	(0.699)	(0.828)
Observations	558	530	499	465
Number of groups	37	37	37	37

	(1)	(2)	(3)	(4)
Agricultural Investment	*t0*	*t* + 1	*t* + 2	*t* + 3
Disaster	-0.286	-1.731	-1.431	1.225
	(0.333)	(1.264)	(2.237)	(2.035)
Disaster#Policy	0.940	1.649	0.395	-0.322
	(0.537)	(0.518)	(1.001)	(0.828)
Observations	184	184	184	184
Number of groups	28	28	28	28

Source: Diallo and Lee (forthcoming).

Longer-term Macroeconomic Impact of Drought

To assess the impact of drought on macroeconomic outcomes in FCS in the section titled “Impact of Climate Shocks on Macroeconomic Outcomes and Food Security,” a dynamic panel autoregressive distributed lag growth model is employed, initially proposed by Dell, Jones, and Olken (2012). The model is modified to express climate variables as deviations from their long-term trend, following the approach pioneered by Kahn and others (2019). This approach allows capture of the effects of climate change (persistent weather deviations from long-term average weather conditions). Autoregressive distributed lag models have been used widely by the recent literature on long-term climate change effects as a more flexible single-equation alternative to cointegration analysis in a panel data context (Kahn and others 2019; Duenwald and others 2022; Maino and Emrullahu 2022; Gigineishvili and others 2023).

The model has the following dynamic autoregressive distributed lag panel specification.[25]

$$\Delta y_{it} \; = \; \alpha + \textstyle\sum_{j=0}^{l} \theta_j \Delta y_{it-j} + \sum_{j=0}^{l} \gamma_j (D_{it-j} - D'_{i-j}) + \epsilon_{it} \qquad (1)$$

where Δy_{it} is growth of real GDP per capita in country *i* in year t, $D^\wedge_{it-j}$ is the deviation of droughts from their long-term trend in country *i* at lag *j*, FCS is a time-varying FCS dummy, and α_i are country fixed effects.[26]

In equilibrium, growth equals its steady state value ($\Delta y *$) and drought deviates from its trend by a constant *D*^.

$$\Delta y_i^{\,*} = \frac{\alpha}{1 - \sum_j^l \theta_j} + \frac{\sum_j^l p_j}{1 - \sum_j^l \theta_j} D^\wedge_i \qquad (2)$$

where the long-term (steady state) growth effect of drought is given by the dynamic multiplier $\frac{\sum_j^l \gamma_j}{1 - \sum_j^l \theta_j}$.

To isolate FCS-specific effects, a time-varying FCS dummy is interacted with the drought variable:

$$\Delta y_{it} = \textstyle\sum_{j=1}^{l} \theta_j \Delta y_{it-j} + \sum_{j=0}^{l} Z_j D^\wedge_{it-j} + \sum_{j=0}^{l} \mu_j D^\wedge_{it-j} * FCS_{it-j} + \sum \emptyset FCS_{it-j} + \alpha_i + \varepsilon_{it} \qquad (3)$$

Equation (3) is estimated on a sample of 159 developing and developed countries over the 1975–2018 period (excluding small island states).[27] Drought conditions are proxied by deviations of the Standardized Precipitation-Evapotranspiration Index (SPEI)—which measures the net soil moisture as a result of precipitation, evaporation (soil), and transpiration (plants) (Vicente-Serrano, Beguería, and López-Moren 2010)—from its long-term trend (estimated using the Hodrick-Prescott filter). To disentangle the macroeconomic effects of drier and more humid climate conditions, the model is fitted separately for negative and positive deviations of SPEI, with negative deviations indicating drier soil conditions and positive deviations indicating more humid soil conditions.[28] Variable sources and definitions are discussed in Annex Table 2.3.

The long-term growth effect of drought in FCS is calculated from the regression coefficients as follows[29]:

$$\frac{\sum_j^l z_j + \sum_j^l \mu_j}{1 - \sum_j^l \theta_j} \qquad (4)$$

The analysis also explores how droughts affect key drivers of per capita GDP growth in fragile states, focusing on crop yields, investment, food production, food imports, and consumption.[30]

---

[25] The β terms cancel out in the derivation (Dell, Jones, and Olken 2012, Annex I).

[26] Qualitatively similar results are obtained using continuous policy variables.

[27] FCS classification is unavailable prior to FY2006. The analysis assumes that FCS that were consistently classified as FCS throughout the entire FY2006–FY23 period were also in the fragile category prior to FY2006.

[28] SPEI varies between +5 and –5 and classifies soil moisture conditions as follows: non-drought (SPEI > –0.5), mild drought (–1 < SPEI < –0.5), moderate drought (–1.5 < SPEI < –1), severe drought (–2 < SPEI < –1.5), and extreme drought (SPEI < –2).

[29] To establish the existence of a long-term relationship, the statistical significance of the coefficients in expression (4) is tested both jointly and separately (for the sum of each coefficient) following the bounds testing procedure (Pesaran, Shin, and Smith 2001), which does not require prior knowledge of the order of integration of variables to draw conclusive inference.

[30] The estimates for positive deviations of the drought index from its trend are statistically insignificant.

Annex Table 2.3. Variable Definitions and Sources for Long-term Analysis

Variables	Definition/Transformation
Dependent Variables	
Real per capita GDP growth	Annual percent change in real per capita GDP (IMF WEO).
Inflation	Annual percent change in end-year consumer price index (IMF WEO). The variable is winsorized to exclude extreme inflation and deflation (above 100 percent).
Investment growth	Log difference of capital stock at constant 2017 national prices multiplied by 100 (Penn World Table).
Crop yield change	Log difference of cereal crop yield index smoothed using the Hodrick-Prescott filter; multiplied by 100 (World Development Indicators).
Food production	Natural logarithm of food production index (World Development Indicators). Food production index covers food crops that are considered edible and that contain nutrients. The index shows the relative level of the aggregate volume of food production for each year in comparison with the base period 2014–16.
Undernourishment	Annual difference in undernourished people as a percentage of the total population (World Development Indicators).
Food imports	Annual difference in food imports as a percentage of total imports (World Development Indicators).
Independent Variables	
Drought	Drought conditions = (SPEI – SPEI_t)*100 where SPEI is the Standardized Evapotranspiration Index and SPEI_t is its trend from Hodrick-Prescott filter (SPEI database).
Primary balance to GDP	Average annual difference in the general government primary balance as a percentage of nominal GDP (World Development Indicators).
Public debt to GDP	Government gross debt as a percentage of nominal GDP (IMF WEO).
Water insecurity index	Water security score on the ND-GAIN Global Adaptation Index measuring vulnerability to water stress scaled between 0 (low) and 1 (high) (ND-GAIN database).
Social expenditure to GDP	General government expense on social programs to nominal GDP (IMF WEO).
Trade to GDP	The sum of exports and imports as a percentage of nominal GDP (IMF WEO).
Regulatory quality index	Change in the regulatory quality index (World Development Indicators). Regulatory quality captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.
Control of corruption index	Change in the control of corruption index (World Development Indicators). Control of corruption captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.
Categorical Variables	
Public debt	The variable takes unity if public debt to GDP exceeds 60 percent (the FCS average).
Social expenditure	The variable takes unity if average social expenditure exceeds 1 percent of GDP (the FCS average).
Trade openness	The variable takes unity if the sum of imports and exports exceeds 73 percent of GDP (the FCS average).
Water insecurity	The variable takes unity if the water insecurity score exceeds 0.37 (the FCS average).

Source: IMF, World Bank, and IMF staff calculations.
Note: FCS = fragile and conflict-affected states; ND-GAIN = Notre Dame Global Adaptation Initiative; WEO = World Economic Outlook database.

The analysis investigates how structural policies could help mitigate the welfare impact of droughts, discussed in the section titled “Macro-critical Policies for Climate Adaptation in FCS,” using interactions of policy variables with the drought variable:

$$\Delta y_{it} = \textstyle\sum_{j=1}^{l} \theta_j \Delta y_{it-j} + \sum_{j=0}^{l} Z_j D_{it-j} + \sum_{j=0}^{l} \mu_j D_{it-j} * FCS_{it-j} + \sum \emptyset FCS_{it-j} + \psi D^{\wedge}_{it-j} * FCS_{it} * POL_{it} + \Omega POL_{it}\, \alpha_i + \varepsilon_{it} \tag{5}$$

where *POL* is a categorical policy variable taking unity for values above the historical mean for FCS.[31]

The analysis looks at fiscal and debt policies, social policy, trade policy, and climate adaptation and structural policies. Separate growth regressions are estimated for each policy variable, considering public debt to GDP and social expenditure to GDP, and the indexes of trade openness, water insecurity, regulatory quality, and control of corruption (Annex Table 2.3 describes the variables). The policy variables are interacted with the SPEI and the FCS dummy and their marginal effect is gauged by the interaction coefficient $\frac{\psi}{1-\sum_j^l \theta_j}$.

The longer-term economic impacts of drought on fragile states are economically meaningful. The point estimates in Annex Table 2.4 show that the growth rates of real GDP per capita, investment, and crop yields in FCS would decline by about 0.2 percentage point annually due to the projected mean deterioration in drought conditions implied by the Intergovernmental Panel on Climate Change low-emission scenario (RCP 2.6). Average food production would be lower by about 8 percent and average inflation higher by close to 1 percentage point. Importantly, the share of food imports in total imports and undernourished persons in the total population would also increase.

The same methodology was used to investigate the long-term macroeconomic impact of *positive* deviations from the drought trend (that is, heavy rainfall). The effects of changes in the SPEI are not symmetric, as the analysis did not find significant results for the longer-term impact of increases in SPEI levels from its long-term trend, which would be associated with heavy rainfall, floods, and storms. Possible explanations of why rising SPEI levels would not impair long-term growth include that floods and storms may be more localized events and shorter in duration than droughts, reconstruction efforts following floods and storms would offset losses in economic activity, and there are benefits of flooding for recessional agriculture in FCS. These results are in line with other findings in the literature which suggest that droughts have a significantly stronger impact than floods on medium-term growth, especially in sub-Saharan Africa (IMF 2020b).

These results are consistent with the emerging climate literature on fragile states and droughts. Maino and Emrullahu (2022) uncover a long-term relationship between temperature and growth of real GDP per capita in fragile states. Zaveri, Damania, and Engle (2023) show that moderate to extreme droughts reduce GDP per capita growth between 0.4 and 0.9 percentage point, on average, with low- and middle-income countries in dry areas sustaining the highest losses. Russ (2020) finds that economic growth is more sensitive to changes in water runoff than rainfall, with runoff of 1 standard deviation reducing short-term GDP growth by 0.4–0.6 percent. IMF (2020a) also finds a significant impact of droughts on medium-term GDP growth. Kotz and others (2023) find that future warming will cause global increases in annual food and headline inflation of 0.9–3.2 and 0.3–1.2 percentage points per year by 2035, respectively. Faccia, Parker, and Stracca (2021) show that higher temperatures play a non-negligible role in driving price developments, especially for emerging market economies.

---

[31] The regulatory quality and control of corruption indexes are included as continuous variables, with negative (positive) values indicating below (above) average regulatory quality and control of corruption.

Annex Table 2.4. Model Estimates: Long-term Impact of Drought Conditions on Fragile States

	Long-term Coefficient [1/]		Impact [2/]
Dependent Variable	**Non-FCS**	**FCS**	**FCS**
Real GDP growth (p.c.)	0.0034 (0.0057)	0.0360** (0.0181)	-0.17 pp
Inflation	-0.0246 (0.0202)	-0.1840*** (0.0619)	0.88 pp
Investment growth	0.003 (0.0059)	0.0396* (0.0214)	-0.19 pp
Food production	0.0080*** (0.0018)	0.0174*** (0.0050)	-8.4 percent
Crop yield growth	-0.0011 (0.0047)	0.0434*** -0.0155	-0.20 pp
Δ Undernourishment [3/]	0.0019 (0.0020)	-0.0122** (0.0058)	0.06 pp
Δ Food imports [3/]	0.0006 (0.0014)	-0.0118** (0.0058)	0.06 pp

Source: Tintchev (forthcoming).
Note: 1/ Long-term sensitivity to negative drought index deviations from its long-term trend (indicating higher aridity).
2/ Impact on long-term values of the average deterioration in drought up to 2060 projected in the low-emission scenario.
3/ Changes in the ratios of undernourished persons to total population and food imports to total imports respectively.
FCS = fragile and conflict-affected states; pp = percentage point.
Robust *t*-statistics in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Scenario analysis investigates fragile states' vulnerability to worsening drought conditions owing to climate change over the next decades. The model is employed to forecast the impact of drought on fragile states' fundamentals under a high emissions scenario (RCP 8.5) and low emission scenario (RCP 2.6) spanning the 2023–60 period (Intergovernmental Panel on Climate Change 2021; Housfather 2019). The scenario analysis illustrates fragile states' vulnerability to droughts. In 2060, FCS' drought-induced per capita income loss is estimated to be about 5 percent higher in the high emissions scenario compared to the low emission scenario, while investment would be lower by 3.5 percent. These results are consistent with the real GDP per capita losses estimated by Kahn and others (2019) for poor countries using temperature deviations from trend. Food production would be lower by 7 percent, the share of food imports in total imports would rise by 2 percent, and inflation would be higher by 2.5 percent. The confluence of lower food production and higher food prices would push an additional 2 percent of fragile states' growing population—about 50 million people—into undernourishment by 2060.[32]

The model is used to analyze how structural macroeconomic policies can help mitigate the impact of drought on long-term macroeconomic outcomes. Real GDP per capita losses in fragile states are amplified by high public debt, low social spending, low trade openness, high water insecurity, weak regulatory quality, and weak control of corruption (Annex Table 2.5). Structural improvements in these indicators help mitigate the impact of droughts on real GDP per capita over the long term. These results are in line with other studies that find that countries with greater fiscal space are better positioned to deal with the adverse consequences of climate change and strengthen their adaptive capacity (Bellon and Massetti 2022).

---

[32] Based on the UN population growth forecast.

The estimates are robust to a range of alternative specifications. To test the robustness of the results, several alternative specifications were employed, including (1) a shorter sample period (by about 10 years), (2) a sample of countries with per capita incomes below $10,000 US dollars, (3) a sample of FCS countries with below average humidity, and (4) alternative specifications of the FCS group. The estimates for the various dependent variables remain overall significant and with the expected sign across the alternative specifications.

Annex Table 2.5. Impact on Growth of Real GDP per Capita in FCS

Interaction Variable	Interaction Coefficient	Impact on Growth [3/]
Public debt to GDP[1/]	0.0274** (0.014)	-0.13 pp
Social expenditure to GDP[1/]	-0.0299** (0.0146)	0.14 pp
Trade opennes[1/]	-0.0255* (0.015)	0.12 pp
Water insecurity[1/]	0.0258* (0.014)	-0.12 pp
Requlatory quality[2/]	-0.0259*** (0.108)	0.12 pp
Control of corruption[2/]	-0.0366*** (0.0107)	0.17 pp

Source: Tintchev (forthcoming).
Notes: 1/ Binary variables taking unity for values above historical mean interacted with droughts and the FCS dummy. Positive (negative) coefficients indicate negative (positive) impact.
2/ Positive (negative) values indicate above (below) average institutional quality.
3/ Marginal impact on real GDP growth after a mean positive shock to the interaction variables (percentage point).
FCS = fragile and conflict-affected states.
Robust t-statistics in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1

Conflict Intensity

To overcome data challenges that often plague economic analysis in fragile countries, the analysis in the section titled “Humanitarian and Conflict Impact of Climate Shocks” is based on a novel data set created using georeferencing to match high-frequency data on conflict, climate, population, and night-light data (as a proxy for economic activity). Matching is done on a monthly frequency at the subregional level (2,848 subregions) across 171 countries including FCS over 2013–22, for a total of 340,842 observations. Specifically, the following indicators are used:

- **Conflict:** The conflict data used in this note is the Uppsala Georeferenced Event Dataset compiled by the Uppsala Conflict Data Program. This data set provides comprehensive information on conflict-related deaths covering the entire world at a geographically disaggregated level. Each conflict event has a pair of coordinates to identify where it occurred. On the fatalities of each event, there are three estimates in the conflict data: a low estimate, a best estimate, and a high estimate. Throughout our analysis, we use the best estimate of fatalities.

- **Population:** Population data are important for normalizing the scale of conflict. The Gridded Population of the World (version 4) is used to calculate population at the regional level. The Gridded Population of the World only covers the years 2000, 2005, 2010, 2015, and 2020.

- **Conflict intensity:** This measure is the main dependent variable and is constructed on the basis of conflict and population by calculating total fatalities per capita at the regional level.

- **Climate variables:** Both precipitation and temperature data are taken from Climatic Research Unit gridded Time Series, which is a widely used climate dataset on a 0.5-degree latitude by 0.5-degree longitude grid over all land domains of the world (except Antarctica). It is derived by the interpolation of monthly climate anomalies from extensive networks of weather station observations.

- **Nighttime lights:** This data is based on the Visible Infrared Imaging Radiometer Suite onboard the Suomi National Polar-orbiting Partnership satellite and covers 2013 to present at a monthly frequency at a regional level.

A cross-country panel model with the following specification is employed:

$$Y_{st} = \beta Climate_{st} + \theta X_{st} + \alpha_s + \delta_t + \varepsilon_{st},$$

where the dependent variable Y_{st} is a continuous variable (in log) measuring conflict intensity severity (number of conflict-related deaths/population); $Climate_{st}$ includes the relevant climate variables, namely temperature and precipitation (in log); X is nighttime lights which serves as a control variable (in log); and α and δ are state and time fixed effects which capture state-specific factors—such as culture and geography—and common shocks, respectively. Standard errors are clustered at the country level.

The results suggest that an increase in temperature is associated with an increase in conflict intensity, while an increase in rainfall is associated with a decline (Annex Table 2.6). Specifically, a 1 percent increase in temperature is associated with a 0.1 percent increase in the intensity of conflict on a monthly basis. A 1 percent increase in precipitation is associated with a 0.02 percent decline in conflict intensity. These results are comparable to Burke and others (2009). These results are robust to the addition of economic activity at the regional level (which is proxied by nightlight data). Using these coefficients, paired with climate projections for high versus low emissions, we extrapolate the impact of climate change on conflict intensity.

Annex Table 2.6. Impact of Climate on Conflict

Temperature	0.041	0.121***			-0.017	0.125***
	(0.23)	(3.25)			(-0.08)	(3.13)
Precipitation			-0.049**	-0.026***	-0.050**	-0.013**
			(-2.23)	(-4.30)	(-2.36)	(-2.02)
Nighttime Lights					-0.012	-0.031
					(-0.20)	(-1.00)
Constant	-12.160***	-12.390***	-11.875***	-11.936***	-11.798***	-12.162***
	(-22.44)	(-111.41)	(-178.79)	(-645.40)	(-11.76)	(-39.61)
Observations	18,161	18,024	18,144	18,010	16,244	16,113
R-squared	0.474	0.661	0.479	0.661	0.488	0.676
Time FE	YES	YES	YES	YES	YES	YES
Individual FE	Country	Region	Country	Region	Country	Region
Controls					YES	YES

Source: Rehman (forthcoming).
Note: Robust *t*-statistics in parentheses. ****p* < 0.01, ***p* < 0.05, **p* < 0.1. FE = fixed effects.

Rainfed versus Irrigated Farms in FCS

To address severe data gaps for FCS, the analysis in the section titled “Climate Vulnerability in Agriculture” is based on a novel data set of farmland with vegetation in FCS, developed using satellite imagery. In agricultural science studies, satellite imagery, particularly those of Landsat, have been widely used to estimate crop acreage and yield (Leslie and others 2017). This analysis applies these geospatial methods to estimate farmland vegetation—as proxy for the area of agricultural lands in production—in FCS from maps of "greenness" (Box 1). These methods are used to generate granular data clearly separating irrigated and rainfed farmlands and non-farmlands. Other papers have applied similar methods to economic analysis of individual countries (Bellora and Bourgeon 2019).

This analysis is the first to create a cross-country data set of this nature for FCS. The data set includes 35 farmlands across 30 FCS (Annex Table 2.7). When selecting farmlands in each FCS, priority is given to major irrigation schemes or areas where rainfed farms are densely located, particularly those in areas affected by conflict. The data set includes 19 irrigated farmlands, which include farms equipped with arrangements for water supply of all types (such as surface, sprinkler, and drip irrigation), and 16 rainfed farmlands, which include farms using seasonal stormwater or makeshift wells and channels. The research period ranges from 1984 to 2021, although farmlands in sub-Saharan Africa tend to have missing data in the 1980s and 1990s covered by older generations of satellites (Landsat 4 and 5).

Annex Table 2.7. List of Farmlands Included in Data Set

Irrigated	Rainfed
Burundi (rice farms in Kirundo Province) Central African Republic (CENTRAPALM palm plantation) Democratic Republic of the Congo (Plantations et Huileries du Congo palm plantation) Ethiopia (Awash Lower Plain scheme) Haiti (rice farms) Iraq (Nineveh region) Kosovo (Pristina area) Lebanon (Bar Elias area) Libya (Great Man-Made River project) Mali (Office du Niger scheme) Mozambique (Limpopo river plain) Myanmar (rice farms in Ayeyarwady delta) Niger (rice farms along Niger river) Nigeria (South Chad Irrigation Project) PNG (Higaturu palm plantation) South Sudan (Aweil scheme) Sudan (Gezira scheme) Syria (Lake Assad scheme) Venezuela (Yaracuy Valley)	Afghanistan (Mazar-i-Sharif area) Burkina Faso (Centre-Ouest Province) Burundi (Kirundo Province) Cameroon (Far North Province) Chad (Logone Occidental Province) Congo-Brazzaville (Brazzaville Province) Eritrea (Adi Ugri area) Guinea-Bissau (Bafata-Gabu Province) Libya (north of Benghazi area) Nigeria (Borno area) Somalia (Beledweyne area) Sudan (Gezira State) Syria (east of Lake Assad) West Bank and Gaza (Gaza Strip) Yemen (Al Hudaydah area) Zimbabwe (Metabeleland North Province)
Source: Koshima (forthcoming).	

A panel regression model is employed to estimate the effect of changes in climate variables on farmland with vegetation in FCS, taking into account access to irrigation. It follows an approach similar to other related studies (for example, Taylor 2022). The model specification is as follows:

$$FARM_{i,t} = \beta_1 RAIN_{i,t} + \beta_2 FLOOD_{i,t} + \beta_3 GW_{i,t} + \beta_4 CONFLICT_{i,t} + \beta_5 LR_{i,t} + \beta_6 EX_{i,t} + \eta_i + \lambda_t + \varepsilon_{i,t} \ ,$$

where $FARM_{i,t}$ is area of farms with vegetation in a farmland I; in year t, $RAIN_{i,t}$ is annual total precipitation; $FLOOD_{i,t}$ is annual frequency of flood events; $GW_{i,t}$ is an annual peak groundwater level; $CONFLICT_{i,t}$ is annual conflict deaths in a province; $LR_{i,t}$ is a dummy variable that equals to 1 for years when land reforms are implemented; and $EX_{i,t}$ captures expansions of irrigated farmland i between year t and the first observed year. η_i and λ_t are, respectively, farmland and year fixed effects that help control for unobserved factors. This specification is estimated separately irrigated and rainfed farms.[33]

---

[33] The analysis does not consider recessional agriculture on floodplains.

The dependent variable, farmland vegetation (*FARM*), is the annual peak of area of farmland with normalized difference vegetation index above 0.3, constructed as described in Box 1. For independent variables, the climate variables are derived from the NASA Giovanni database. In addition to annual total precipitation (*RAIN*) and groundwater measured by the annual peak of land water storage (*GW*), the model includes the frequency of flood events (*FLOOD*) that is influenced more by rainfall patterns than annual total precipitation and is measured by the number of days when surface soil moisture exceeds a threshold value (6.5 to 7 kg/m^2). Adding measures of groundwater and flooding, in addition to precipitation, is an innovation of this analysis compared to other studies and provides a more comprehensive picture of water sources for agriculture in these countries. In addition to climate variables, the model includes controls for conflict deaths (particularly relevant to FCS), land reform periods (which had significant impact in Zimbabwe and Venezuela), and expansion projects of irrigation schemes. Data on province-level conflict deaths are obtained from the Uppsala Conflict Data Program.

Annex Table 2.8 shows the regression results separately for 16 rainfed farmlands and 19 irrigated farmlands. Coefficients of all climate variables (*RAIN*, *FLOOD*, *GW*) are statistically significant with economically meaningful signs for rainfed farms, controlling for conflict. In contrast, none of the coefficients are statistically significant for irrigated farmlands. These findings are in line with other studies that find that irrigated farms are less sensitive to climate shocks than rainfed farms (Li and Troy 2018 for the US Midwest; Gatti, Baylis, and Crost 2020 for rice production in Indonesia; Rao 2012 for sugarcane in southern India). The coefficients of control variables (*CONFLICT*, *LR*, *EX*) show mixed results, suggesting that their relationships can be confounding and specific to each farmland as discussed in the case studies.

Annex Table 2.8. Results of Baseline Estimation (Dependent Variable: *FARM*)

Sample	Irrigated farms	Rainfed farms	
RAIN	0.1215	1.6338	*
	[0.25050]	[0.88177]	
FLOOD	-2.3109	-14.8085	**
	[2.52726]	[6.71930]	
GW	-0.2517	2.9133	*
	[0.92623]	[1.60900]	
CONFLICT	-0.1037	0.0276	
	[0.14411]	[0.03165]	
LR	-571.9	-8359.7	***
	[358.4]	[99.5]	
EX	0.6634	----	
	[0.45468]	----	
Observations	510	412	
Number of farmlands	19	16	
R squared	0.0783	0.3499	
Farmland FE	Y	Y	
Time FE	Y	Y	

Source: Koshima (forthcoming).
Note: Robust standard errors are shown in parentheses below the coefficient estimates. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. FE = fixed effects.

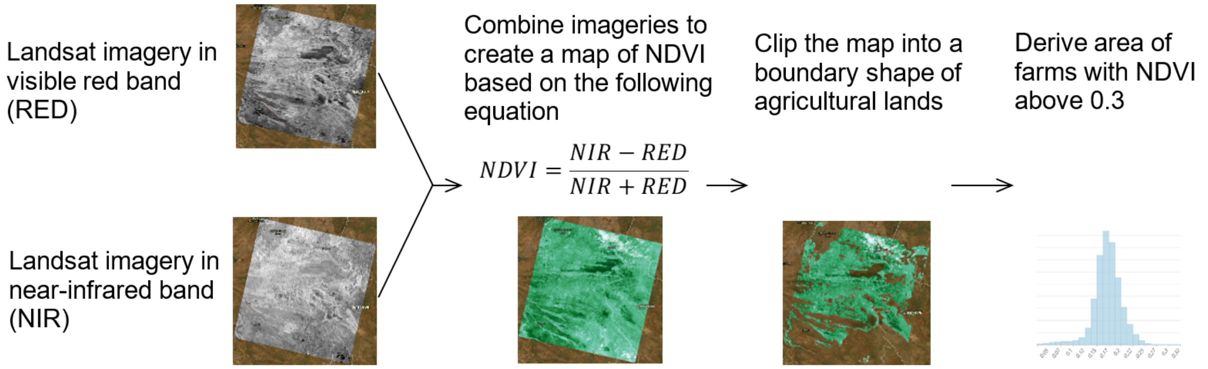
Annex Box 2.1. Novel Data Set Created from Maps of Greenness for Fragile and Conflict-Affected States

Maps of "greenness" were created to measure the area of agricultural lands that have vegetation for selected areas in fragile and conflict-affected states. This note uses a map of normalized difference vegetation index (NDVI), which has been the most commonly used approach to measure density of green on a land (see, for example, Leslie, Serbina, and Miller 2017 for usage of NDVI for agricultural monitoring in the United States). NDVI is based on the vegetation's interactions with different wavelengths of lights (NASA 2018). When vegetation is green, leaves reflect strongly near-infrared light but little red visible light. In contrast, when vegetation is maturing or there is no vegetation, they reflect less near-infrared light but strongly red visible light. NDVI is created by computing the difference in reflection of visible red (*RED*) and near-infrared (*NIR*) light in the following equation:

$$NVDI = \frac{NIR - RED}{NIR + RED}$$

Methods of geospatial analysis have been used to derive granular data from Landsat imagery. There are some existing datasets of NDVI, but these do not have sufficient granularity to distinguish rainfed and irrigated farms and natural vegetation. Koshima (forthcoming) establishes the geospatial analysis procedure to generate time-series of farmland with vegetation (Annex Box Figure 2.1.1). Landsat imagery obtained from the USGS database are used as the data source because it provides high resolution imageries (30m×30m) for more than 40 years. Annex Box Figure 2.1.1 explains the methodological approach.

Annex Box Figure 2.1.1. Geospatial Analysis Procedures for Farmland with Vegetation



Source: Koshima (forthcoming).
Note: NDVI = Normalized Difference Vegetation Index.

- **Natural vegetation:** Natural vegetation is eliminated by rigorously digitizing a boundary of agricultural lands based on satellite imagery for each research area. In addition, a new boundary of agricultural lands is digitized whenever the shape of agricultural lands changes due to expansion of irrigation.

- **Threshold:** Area that has NDVI higher than 0.3 is considered to have vegetation. NDVI ranges from –1.0 to +1.0. Negative values indicate a water basin. Higher positive NDVI indicates lands being more "green." While each crop shows a different NDVI value, Johnson and others (2021) propose a NDVI value of 0.3 for Landsat 8 as a cut-off value, below which vegetation is likely to be noise or irrelevant to yields (for example, weeds). As an exception, unique threshold values are determined for palm vegetation, which are readily apparent in satellite imagery. For older generations of Landsat, threshold values are adjusted by comparing maps of an overlapping period when both imageries of older and newer generations are available.

Annex 3. Country Case Studies: Impact of Fragilities on Irrigation and Agriculture

Iraq

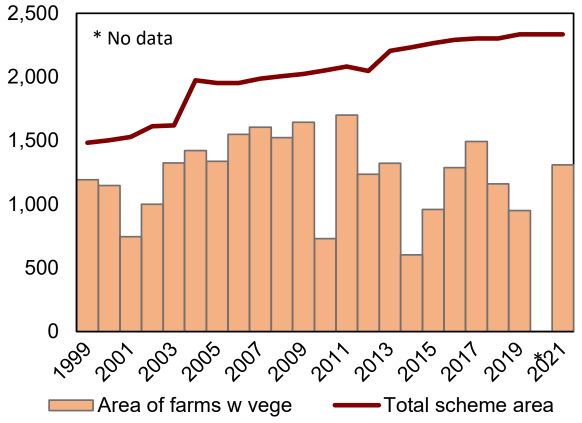
In northern Iraq, the intensive battle with the Islamic State in Iraq and Syria (ISIS) physically destroyed irrigation infrastructure and wiped out farmlands in its controlled area. Nineveh Province is the agricultural heartland of Iraq and includes the Jazeera irrigation scheme, which is connected to the Tigris River through a long feeder canal powered by large pumping systems in Mosul Dam, and other vast farmlands with traditional irrigation. The farmland with vegetation in this region had improved and stabilized after 2003, except for 2008 and 2009 when the local security situation deteriorated. However, when ISIS invaded and occupied the region in 2014, the farmland with vegetation almost completely disappeared. As reported in Regional Food Security Analysis Network (2016) and various news articles, ISIS actively used irrigation infrastructure for their battles and set explosives in canal networks. The region was recaptured in 2017, but farmers were unable to resume agriculture in this region, including because of lack of financing to reconstruct the infrastructure (Bourhrous, Fazil, and O’Driscoll 2022). As a result, farmland with vegetation in this area remains almost nonexistent until today.

Mali

The security crisis since 2012 has deteriorated infrastructure of the Office du Niger irrigation scheme and increased risks of flooding within the scheme. The Office du Niger is a large irrigation scheme along Niger River in central Mali, which was originally created in the 1930s. Based on satellite imagery, it is estimated that around 30 percent of scheme was unplanted on average between 1999–2011 and the share of unused farms has risen to around 50 percent between 2012–21 (Annex Figure 3.1). While there is no official analysis available for the impact of the security crisis on the Office du Niger, the estimated vegetation losses seem to be linked to increased flooding of the area, which appears to be caused by a deterioration of the drainage system as farmers fled the area due to security risks (Annex Figure 3.2).

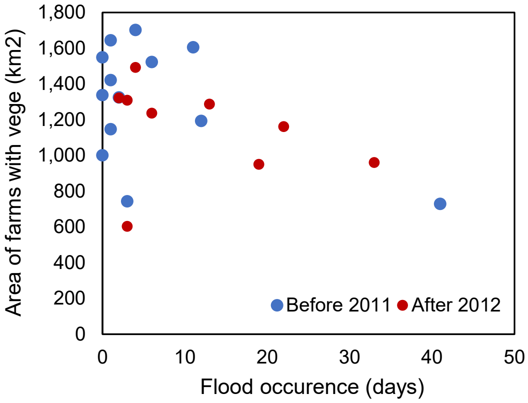
Annex Figure 3.1. Mali—Office du Niger Scheme: Farmland with Vegetation

(Square kilometers)



Source: Koshima (forthcoming).
Note: Vege = vegetation.

Annex Figure 3.2. Mali—Office du Niger Scheme: Farmland with Vegetation and Floods



Source: Koshima (forthcoming).
Note: Vege = vegetation.

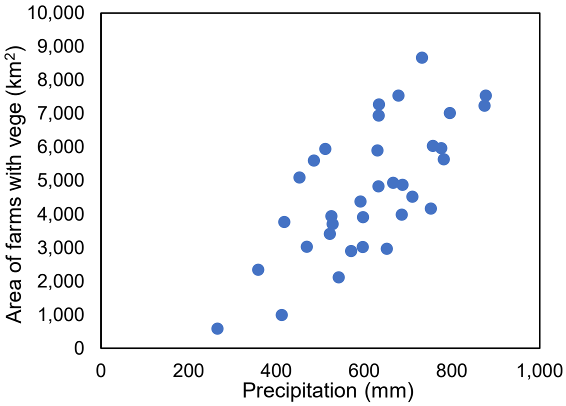
Mozambique

Damages by floods increased sensitivity of irrigated farms in the Limpopo River plain to climate variables until a long overdue repair was carried out. Because of its semiarid climate, irrigation from the Limpopo River is an important source of water supply for many farms in the plain. However, the area has been frequently stricken by cyclones. In particular, Cyclone Leon-Eline in 2000 caused catastrophic floods, which inundated the entire lower Limpopo plain. Some rehabilitation efforts were undertaken after the 2000 floods (Ganho and Woodhouse 2014). However, farms remained vulnerable to droughts and flooding. For example, major droughts in southern Africa in 2007 devastated the farmland with vegetation. In the 2010s, additional resources from international development partners were mobilized for repair and maintenance work (World Bank 2016; African Development Bank 2012).[34] This maintenance work increased the resilience of irrigation infrastructure to flooding and drought. When Cyclones Idai and Eloise struck the region in 2019 and 2021, respectively, farmland with vegetation decreased but to a much lesser extent than in 2000.

Sudan

Lack of proper maintenance contributed to the shrinking by half of the functioning area of the Gezira irrigation scheme, which is a large-scale gravity irrigation system for cotton, groundnut, sorghum, and wheat (Al Zayed and others 2015; Goelnitz and Al-Saidi 2020). The scheme was created originally in the 1920s and expanded from around 4,000 square kilometers to 8,000 square kilometers in the 1960s. For the last three decades, farmland with vegetation within the scheme has been sharply correlated to precipitation, behaving not much differently from rainfed farms (Annex Figure 3.3). Although there are several reasons for malfunctioning of the water supply, lack of proper maintenance has caused accumulation of sediment and clogging of canals and pipes. Although the quantity of sediment removal was increased in the 2000s, removal works were not properly implemented and instead damaged canal systems and facilitated sediment accumulation (Osman 2015). The situation appears to have worsened in the late 2010s, as the farmland with vegetation stagnated at around 3,500 square kilometers, which is half of the intended coverage, notwithstanding good rainfall.

Annex Figure 3.3. Sudan—Gezira Scheme: Farmland with Vegetation and Precipitation



Source: Koshima (forthcoming).
Note: Vege = vegetation.

Ethiopia

An expansion project altered the groundwater level and exacerbated salinity hazards in the Lower Awash Plain irrigation scheme, which has been largely abandoned. Since the 1950s, irrigation projects have been actively developed in the Awash River Basin where around 1,600 square kilometers of irrigated lands exist in total (Tufa 2021). For an irrigation scheme in an arid area, which generally has higher water and soil salinity, drainage is crucial to prevent saline groundwater from rising upward and contaminating farmlands (Criddle and Haise 1957). However, for the Lower Awash Plain irrigation scheme, which is an arid area, the drainage system seems to have been poorly designed (Nanesa 2021). The scheme was largely abandoned by the late 2000s due mainly to salinity hazard, exacerbated by various other factors (including population density, wetland degradation, and administrative issues). However, an expansion project was implemented in 2013 to increase the scheme from around 300 square kilometers to 500 square kilometers following the completion of the nearby Tendaho Dam. This expansion project does not seem to have constructed an adequate drainage system either,

---

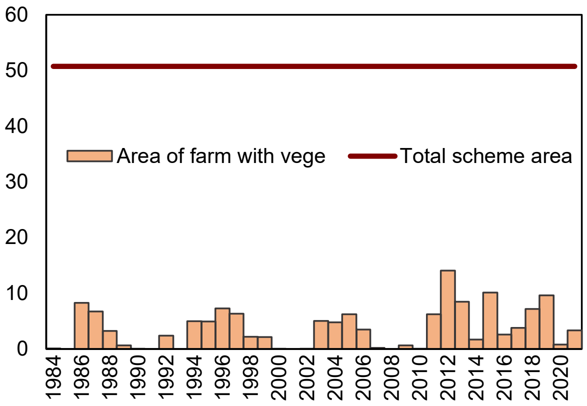
[34] The 2022 Article IV for Mozambique discusses the national strategies for reduced disaster risk and climate change adaptation (IMF 2022d).

as the groundwater level increased, bringing more salts. After the expansion project, the farmland with vegetation shrank rapidly to a lower level than before the expansion.

South Sudan

The Aweil irrigation scheme was abandoned after decades-long neglect of maintenance (Annex Figure 3.4). The Aweil scheme is a gravity irrigation system for rice in Northern Bahr el-Ghazal State, using water from the Lol River. It was originally built in the 1940s and gradually expanded to around 50 square kilometers by the 1960s (Tombe 2019). Since the Second Sudanese Civil War in the region started in 1983, no maintenance has been undertaken due to absence of funding and technical personnel (Tombe 2019). With canals being buried under sediment and natural vegetation, the infrastructure has effectively ceased to exist. The scheme has been largely abandoned except for a fraction of the area used as rainfed farms.

Annex Figure 3.4. South Sudan—Aweil Scheme: Farmland with Vegetation
(Square kilometers)

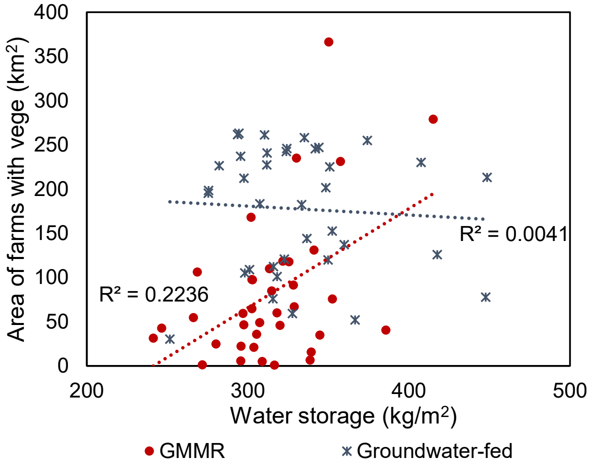


Source: Koshima (forthcoming).
Note: Vege = vegetation.

Libya

Unstable water supply from the GMMR project contributed to the abandonment of farms in Benghazi area, while the farms that remained became more sensitive to climate shocks. The GMMR project takes water from large groundwater aquifers in the middle of Sahara Desert and distributes it to major cities and agricultural lands along Mediterranean coastline through 4,000 kilometers of pipelines. The irrigation scheme in south of Benghazi city was built as part of the network and designed to take water from two reservoirs of the GMMR. Although the GMMR has been providing potable water to urban areas at costs much lower than desalinization, satellite imagery suggests that water supply has been unstable at least in this irrigation scheme. For example, in the 1990s, one reservoir was always empty and the other also lost water frequently. Farmland with vegetation plummeted particularly when neither reservoir had water. Because of the unreliable water supply, a large area of the scheme was abandoned particularly after the beginning of the Second Civil War in 2014. For the remaining farms in the scheme, farmland with vegetation is now more strongly correlated to the local groundwater level (measured by water storage) than groundwater-fed farms just 80 kilometers north of the scheme (Annex Figure 3.5).

Annex Figure 3.5. Libya—GMMR: Farmland with Vegetation and Groundwater

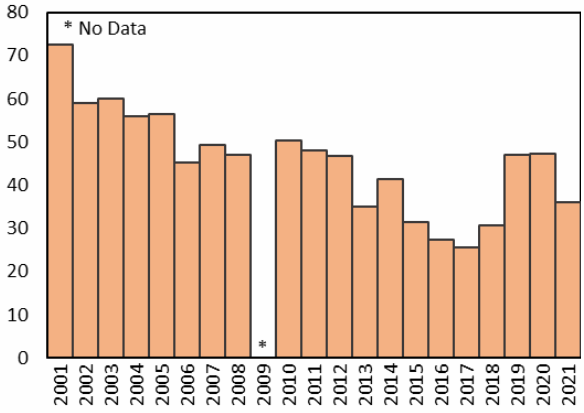


Source: Koshima (forthcoming).
Note: GMMR = Great Man-Made River; vege = vegetation.

Democratic Republic of Congo

A private-led scheme failed to make investments needed to turn around an ailing palm plantation, amid governance concerns. The Plantations et Huileries du Congo is one of the largest and oldest palm plantations in the country, created by a multinational company in the early twentieth century. However, after the Congo War in the late 1990s, the foreign company was struggling to keep up maintenance of the plantation, which showed rapid decline in the area of palm vegetation in the 2000s (Annex Figure 3.6). Although the company changed foreign ownership in 2009 and again in 2020, palm oil production has continued on a downward trend. The company has also been plagued by questions around governance (GRAIN and RIAO-RDC 2015; Oakland Institute 2022).

Annex Figure 3.6. Democratic Republic of the Congo—PHC: Area of Palm Vegetation
(Square kilometers)

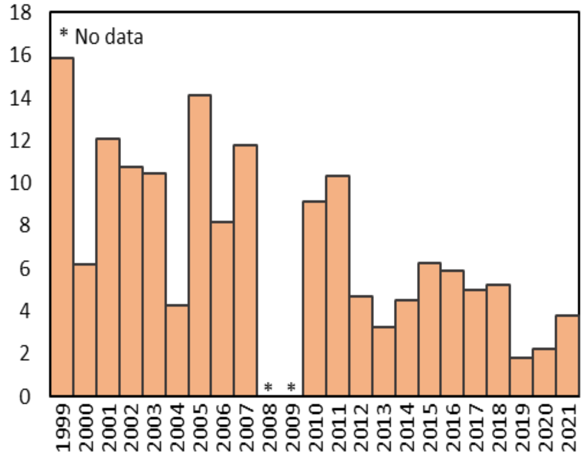


Source: Koshima (forthcoming).
Note: PHC = Plantations et Huileries du Congo.

Central African Republic

A palm plantation project implemented through a state-owned enterprise (SOE) has been underperforming significantly in absence of adequate investments and oversight. In 1986, the Centrafricaine des Palmiers project was launched to create around 25 square kilometers of palm plantations managed by an SOE. However, production remained on a declining trend because the SOE was unable to make investments needed to replace aged or damaged palm trees and upgrade machines and equipment at the processing plant (Carrere 2013). In the 2000s, palm vegetation covered only around one-third of the total plantation area (Annex Figure 3.7). The situation deteriorated significantly with the beginning of the civil war in 2012. In recent years, the plantation has been abandoned except for a small area, which is likely being cultivated by private farmers who purchased the palm trees from the SOE in the 1990s (Carrere 2013).

Annex Figure 3.7. Central African Republic—CENTRAPALM: Area of Palm Vegetation
(Square kilometers)



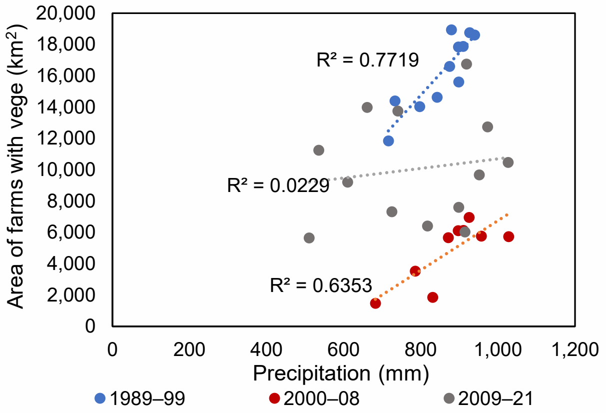
Source: Koshima (forthcoming).
Note: CENTRAPALM: Centrafricaine des Palmiers.

Zimbabwe

The Fast-Track Land Reform Program initially damaged agriculture production but subsequent redesigned policies supported an increase in tobacco production. When the Fast-Track Land Reform Program began in 2000, commercial farmlands were confiscated and distributed to groups without the knowledge or financing to operate large scale farming. During the early 2000s, vast crop farms in northwest Zimbabwe almost vanished. However, farmlands revived in the region following a shift to tobacco production since 2009. Together with various climate adaptation measures taken by the government (see IMF 2022d), farmland in the region has become less sensitive to changes in rainfall (Annex Figure 3.8).

Annex Figure 3.8. Zimbabwe—Metabeleland North Province: Farmland with Vegetation

(Square kilometers)



Source: Koshima (forthcoming).
Note: Vege = vegetation.

References

Abel, Guy J., Michael Brottrager, Jesus Crespo Cuaresma, and Raya Muttarak. 2019. “Climate, Conflict and Forced Migration.” *Global Environmental Change* 54: 239–49.

Adger, W. Neil, Juan M. Pulhin, Jon Barnett, Geoffrey D. Dabelko, Grete K. Hovelsrud, Marc Levy, Úrsula Oswald Spring, and Coleen H. Vogel. 2014. “Human Security.” In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*, edited by Christopher B. Field, Vicente R. Barros, David Jon Dokken, Katharine J. Mach, Michael D. Mastrandrea, T. Eren Bilir, Monalisa Chatterjee, Kristie L. Ebi, Yuka Otsuki Estrada, Robert C. Genova, Betelhem Girma, Eric S. Kissel, Andrew N. Levy, Sandy MacCracken, Patricia R. Mastrandrea, and Leslie L. White, 755–91. New York: Cambridge University Press.

African Development Bank. 2012. “Project Appraisal Report: Baixo Limpopo Irrigation and Climate Resilience Project.” Abidjan, Côte d’Ivoire.

African Union. 2022. “Climate Change and Resilient Development Strategy and Action Plan (2022-2032)”

Al Zayed, Islam Sabry, Nadir Ahmed Elagib, Lars Ribbe, and Jürgen Heinrich. 2015. “Spatio-temporal Performance of Large-Scale Gezira Irrigation Scheme, Sudan.” *Agricultural Systems* 133: 131–42.

Aligishiev, Zamid, Emanuele Massetti, and Matthieu Bellon. 2022. “Macro-Fiscal Implications of Adaptation to Climate Change.” IMF Staff Climate Note 2022/002, International Monetary Fund, Washington, DC.

Aydin, Ozlem, Bryn Battersby, Fabien Gonguet, Claude Wendling, Jacques Charaoui, Murray Petrie, and Suphachol Suphachalasai. 2022. “How to Make the Management of Public Finances Climate Sensitive—“Green PFM.” How To Note 22/06, International Monetary Fund, Washington, DC.

Baptista, Diogo Miguel Salgado, Mai Farid, Dominique Fayad, Laurent Kemoe, Loic S. Lanci, Pritha Mitra, Tara S. Muehlschlegel, Cedric Okou, John A. Spray, Kevin Tuitoek, and Filiz D. Unsal. 2022. “Climate Change and Chronic Food Insecurity in Sub-Saharan Africa.” IMF Departmental Paper 2022/016, International Monetary Fund, Washington, DC.

Barnett, Jon, and W. Neil Adger. 2007. “Climate Change, Human Security and Violent Conflict.” *Political Geography* 26 (6): 639–55.

Batten, Sandra. 2018. “Climate Change and the Macro-economy: A Critical Review.” Working Paper 706, Bank of England, London.

Bayoumi, Tamim, Saad Quayyum, and Sibabrata Das. 2021. “Growth at Risk from Natural Disasters.” IMF Working Paper 2021/234, International Monetary Fund, Washington, DC.

Belianska, Anna, Nadja Bohme, Kailhao Cai, Yoro Diallo, Saanya Jain, Giovanni Melina, Pritha Mitra, Marcos Poplawski Ribeiro, and Solo Zerbo. 2022. “Climate Change and Select Financial Instruments: An Overview of Opportunities and Challenges for Sub-Saharan Africa.” IMF Staff Climate Note 2022/009, International Monetary Fund, Washington, DC.

Bellon, Matthieu, and Emanuele Massetti. 2022. “Planning and Mainstreaming Adaptation to Climate Change in Fiscal Policy.” IMF Staff Climate Note 2022/003, International Monetary Fund, Washington, DC.

Bellora, Cecilia, and Jean-Marc Bourgeon. 2019. “Food Trade and Biodiversity Effects.” *International Economic Review* 60: 1957–99.

Bjornlund, Vibeke, Henning Bjornlund, and Andre F. Van Rooyen. 2020. “Why Agricultural Production in Sub-Saharan Africa Remains Low Compared to the Rest of the World –– A Historical Perspective.” *International Journal of Water Resources Development* 36 (sup1): S20–S53.

Bourhrous, Amal, Shivan Fazil, and Dylan O’Driscoll. 2022. “Post-conflict Reconstruction in the Nineveh Plains of Iraq: Agriculture, Cultural Practices and Social Cohesion.” SIPRI, Stockholm.

Bueno de Mesquita, Bruce, and Alastair Smith. 2017. "Political Succession: A Model of Coups, Revolution, Purges, and Everyday Politics." *Journal of Conflict Resolution* 61 (4): 707–43.

Burke, Marshall, Solomon M. Hsiang, and Edward Miguel. 2015. "Global Non-linear Effect of Temperature on Economic Production." *Nature* 527: 235–39.

Burke, Marshall B., Edward Miguel, Shanker Satyanath, John A. Dykema, and David B. Lobell. 2009. "Warming Increases the Risk of Civil War in Africa." *PNAS* 106 (49): 20670–74.

Cappelli, Federica, Caterina Conigliani, Davide Consoli, Valeria Costantinim and Elena Paglialunga. 2023. "Climate Change and Armed Conflicts in Africa: Temporal Persistence, Non-linear Climate Impact and Geographical Spillovers." *Economia Politica* 40: 517–60.

Carrere, Ricardo. 2013. "Oil Palm in Africa." WRM Series on Tree Plantations 15, World Rainforest Movement, Montevideo, Uruguay.

Cebotari, Aliona, and Karim Youssef. 2020. "Natural Disaster Insurance for Sovereigns: Issues, Challenges and Optimality." IMF Working Paper 20/3, International Monetary Fund, Washington, DC.

Chen, Chaoran, Diego Restuccia, and Raül Santaeulàlia-Llopis. 2017. "The Effects of Land Markets on Resource Allocation and Agricultural Productivity." NBER Working Paper 24034, National Bureau of Economic Research, Cambridge, MA.

Criddle, Wayne D., and Howard R. Haise. 1957. "Irrigation in Arid Regions." In *Yearbook of Agriculture 1957*, 359–67. Washington, DC: US Congress House of Representatives.

Dell, Melissa, Benjamin F. Jones, and Benjamin A. Olken. 2009. "Temperature and Income: Reconciling New Cross-Sectional and Panel Estimates." *American Economic Review* 99 (2): 198–204.

Dell, Melissa, Benjamin F. Jones, and Benjamin A. Olken. 2012. "Temperature Shocks and Economic Growth: Evidence from the Last Half Century." *American Economic Journal: Macroeconomics* 4 (3): 66–95.

Desbureaux, Sébastien, and Aude-Sophie Rodella. 2019. "Drought in the City: The Economic Impact of Water Scarcity in Latin American Metropolitan Areas." *World Development* 114: 13–27.

Diallo, Yoro, and Jaewoo Lee. Forthcoming. "Resilience Building in Fragile States: Addressing the Macroeconomic Consequences of Climate-Related Natural Disasters." IMF Working Paper, International Monetary Fund, Washington, DC.

Duenwald, Christoph, Yasser Abdih, Kerstin Gerling, Vahram Stepanyan, Abdullah Al-Hassan, Gareth Anderson, Anja Baum, Sergejs Saksonovs, Lamiae Agoumi, Chen Chen, Mehdi Benatiya Andaloussi, Sahra Sakha, Faten Saliba, and Jesus Sanchez. 2022. "Feeling the Heat—Adapting to Climate Change in the Middle East and Central Asia." IMF Departmental Paper 2022/008, International Monetary Fund, Washington, DC.

Faccia, Donata, Miles Parker, and Livio Stracca. 2021. "Feeling the Heat: Extreme Temperatures and Price Stability." ECB Working Paper 2626, European Central Bank, Frankfurt, Germany.

Food and Agriculture Organization of the United Nations. 2021. *Climate-Smart Agriculture Case Studies 2021: Projects from Around the World*. Rome.

Fouad, Manal, Natalija Novta, Gemma Preston, Todd Schneider, and Sureni Weerathunga. 2021. "Unlocking Access to Climate Finance for Pacific Island Countries." IMF Departmental Paper 2021/020, International Monetary Fund, Washington, DC.

Ganho, Ana Sofia, and Phil Woodhouse. 2014. "Oportunidades e Condicionalismos da Agricultura no Regadio do Chókwè." *Desafios para Moçambique* 163–94.

Gatti, Nicolas, Kathy Baylis, and Benjamin Crost. 2020. "Can Irrigation Infrastructure Mitigate the Effect of Rainfall Shocks on Conflict? Evidence from Indonesia." *American Journal of Agricultural Economics* 103: 211–31.

Ghesquiere, Francis, and Olivier Mahul. 2010. “Financial Protection of the State Against Natural Disasters: A Primer.” World Bank Policy Research Working Paper 5429, World Bank, Washington, DC.

Ghimire, Ramesh, and Susana Ferreira. 2016. “Floods and Armed Conflict.” *Environment and Development Economics* 21 (1): 23–52.

Gigineishvili, Nikoloz, Iulia Ruxandra Teodoru, Narek Karapetyan, Yulia Ustyugova, Jean van Houtte, Jiri Jonas, Wei Shi, Shant Arzoumanian, Kalin Tintchev, Maxwell Tuuli, Faten Saliba, Farid Talishli, Moataz El Said, and Fernanda Brollo. 2023. “Paving the Way to more Resilient, Inclusive and Greener Economies in Caucasus and Central Asia.” IMF Departmental Paper 2023/004, International Monetary Fund, Washington, DC.

Gignoux, Jérémie, Karen Macours, Daniel Stein, and Kelsey Wright. 2022. “Input Subsidies, Credit Constraints, and Expectations of Future Transfers: Evidence from Haiti.” *American Journal of Agricultural Economics* 105 (3): 809–35.

Global Center for Adaptation. 2022. “State and Trends in Adaptation Report 2022.” Rotterdam, The Netherlands.

Goelnitz, Anna, and Mohammad Al-Saidi. 2020. “Too Big to Handle, Too Important to Abandon: Reforming Sudan’s Gezira Scheme.” *Agricultural Water Management* 241: 106396.

GRAIN and RIAO-RDC. 2015. “Agro-Colonialism in the Congo.” Barcelona, Spain.

Hallegatte, Stéphane, and Patrice Dumas. 2009. "Can natural disasters have positive consequences? Investigating the role of embodied technical change." Ecological economics 68.3 (2009): 777–786.

Hallegatte and others. 2016. “Shock waves: managing the impacts of climate change on poverty”. World Bank Publications, 2016

Harari, Mariaflavia, and Eliana La Ferrara. 2018. “Conflict, Climate, and Cells: A Disaggregated Analysis.” *The Review of Economics and Statistics* 100 (4): 594–608.

Housfather, Zeke. 2019. “CMIP6: The Next Generation of Climate Models Explained.” *Climate Modelling*, *Carbon Brief*, December 2.

Ide, Tobias, Carl Bruch, Alexander Carius, Ken Conca, Geoffrey D. Dabelko, Richard Matthew, and Erika Weinthal. 2021. “The Past and Future(s) of Environmental Peacebuilding.” *International Affairs* 97 (1): 1–16.

Ide, Tobias, Micahel Brzoska, Jonathan F. Donges, and Carl-Friedrich Schleussner. 2020. “Multi-Method Evidence for When and How Climate-related Disasters Contribute to Armed Conflict Risk.” *Global Environmental Change* 62: 102063.

Intergovernmental Panel on Climate Change (IPCC). 2021. “Climate Change 2021: The Physical Science Basis.” Geneva.

Intergovernmental Panel on Climate Change (IPCC). 2022. “Climate Change 2022: Impacts, Adaptation and Vulnerability.” Geneva.

Internal Displacement Monitoring Centre. 2021. “Global Report on Internal Displacement”

International Federation of Red Cross and Red Crescent Societies. 2019. “The Cost of Doing Nothing--the Humanitarian Price of Climate Change And How It Can Be Avoided.” Geneva.

International Monetary Fund (IMF). 2016. “Small States’ Resilience to Natural Disasters and Climate Change -— Role for the IMF.” IMF Policy Paper, Washington, DC.

International Monetary Fund (IMF). 2017. “The Effects of Weather Shocks on Economic Activity: How Can Low-Income Countries Cope?” In *World Economic Outlook*, Washington, DC, October.

International Monetary Fund (IMF). 2018. “Review of 1997 Guidance Note on Governance —– A Proposed Framework for Enhanced Fund Engagement.” Washington, DC.

International Monetary Fund (IMF). 2019. "Building Resilience in Developing Countries Vulnerable to Large Natural Disasters." IMF Policy Paper, Washington, DC.

International Monetary Fund (IMF). 2020a. *World Economic Outlook: A Long and Difficult Ascent*. Washington, DC, October.

International Monetary Fund (IMF). 2020b. *Regional Economic Outlook: Sub-Saharan Africa—Adapting to Climate Change in Sub-Saharan Africa*. Washington, DC, April.

International Monetary Fund (IMF). 2021. *Regional Economic Outlook, Western Hemisphere—A Long and Winding Road to Recovery*. Washington, DC, October.

International Monetary Fund (IMF). 2022a. "The IMF Strategy for Fragile and Conflict-Affected States." IMF Policy Paper, Washington, DC.

International Monetary Fund (IMF). 2022b. "IMF Engagement on Social Safety Net Issues in Surveillance and Program Work." IMF Technical Notes and Manuals 22/007, Washington, DC.

International Monetary Fund (IMF). 2022c. "Proposal to Establish a Resilience and Sustainability Trust." IMF Policy Paper 2022/013, Washington, DC.

International Monetary Fund (IMF). 2022d. "Zimbabwe: Article IV Staff Report." IMF Country Report 2022/112, Washington, DC.

International Monetary Fund (IMF). 2022e. "Solomon Islands Selected Issues." IMF Country Report 22/15, Washington, DC.

International Monetary Fund (IMF). 2022f. "Democratic Republic of Timor-Leste Selected Issues." IMF Country Report 22/308, Washington, DC.

International Monetary Fund (IMF). 2023. *Regional Economic Outlook: Sub-Saharan Africa—Closing the Gap: Concessional Climate Finance and Sub-Saharan Africa*. Washington, DC, April.

Johnson, David M., Arthur Rosales, Richard Mueller, Curt Reynolds, Ronald Frantz, Assaf Anyamba, Ed Pak, and Compton Tucker. 2021. "USA Crop Yield Estimation with MODIS NDVI: Are Remotely Sensed Models Better Than Simple Trend Analyses?" *Remote Sensing* 13: 4227.

Johnstone, Sarah, and Jeffrey Mazo. 2011. "Global Warming and the Arab Spring." *Survival* 53 (2): 11–17.

Kabundi, Alain N., Monfort Mlachila, and Jiaxiong Yao. 2022. "How Persistent Are Climate-Related Price Shocks? Implications for Monetary Policy." IMF Working Paper 22/207, International Monetary Fund, Washington, DC.

Kadigi, Reuben M. J., Girmay Tesfay, Alfred Bizoza, Genet Zibadou, and David Zilberman. 2019. "Irrigation and Water Use Efficiency in Sub-Saharan Africa." *Gates Open Research* 3: 587.

Kahn, Matthew E, Kamiar Mohaddes, Ryan N. C. Ng, M. Hashem Pesaran, Mehdi Raissi, and Jui-Chung Yang. 2019. "Long-Term Macroeconomic Effects of Climate Change: A Cross-Country Analysis." IMF Working Paper 19/215, International Monetary Fund, Washington, DC.

Koshima, Y. Forthcoming. "Climate Challenges in FCS: Geospatial Analysis of the Impact of Climate Shocks on Agriculture." IMF Working Paper, International Monetary Fund, Washington, DC.

Kotz, Maximilian, Friderike Kuik, Eliza Lis, and Christiane Nickel. 2023. "The Impact of Global Warming on Inflation: Average, Seasonality, and Extremes." ECB Working Paper Series 2821, European Central Bank, Frankfurt, Germany.

Kotz, Maximilian, Anders Levermann, and Leonie Wenz. 2022. "The Effect of Rainfall Changes on Economic Production." *Nature* 601: 223–27.

Koubi, Vally. 2019. "Climate Change and Conflict." *Annual Review of Political Science* 22 (1): 343–60.

Leslie, Colin R., Larisa O. Serbina, and Holly M. Miller. 2017. "Landsat and Agriculture – Case Studies on the Uses and Benefits of Landsat Imagery in Agricultural Monitoring and Production." US Geological Survey, Fot Collins, CO.

Li, X., and T. J. Troy. 2018. "Changes in Rainfed and Irrigated Crop Yield Response to Climate in the Western US." *Environmental Research Letters* 13 (6): 064031.

Maino, Rodolfo, and Drilona Emrullahu. 2022. "Climate Change in Sub-Saharan Africa's Fragile States: Evidence from Panel Estimations." IMF Working Paper 22/54, International Monetary Fund, Washington, DC.

Miguel, Edward, Shanker Satyanath, and Ernest Sergenti. 2004. "Economic Shocks and Civil Conflict: An Instrumental Variables Approach." *Journal of Political Economy* 112 (4): 725–53.

Nanesa, Kebede. 2021. "Awash River's Ongoing Irrigation Practices, Future Projects and its Impacts on the Environment of Awash River Basin." *Irrigation and Drainage Systems Engineering* 10 (6).

NASA. 2018. "NDVI Using Units in Calculations." https://mynasadata.larc.nasa.gov/sites/default/files/2019-03/NDVI%20Using%20Units%20in%20Calculations_1.pdf

Noy, Ilan. 2009. "The Macroeconomic Consequences of Disasters." *Journal of Development Economics* 88 (2): 221–31.

Oakland Institute. 2022. "Meet the Investors Behind the PHC Oil Palm Plantations in DRC." Oakland, CA.

Osman, Ishraga Sir Elkhatim. 2015. "Impact of Improved Operation and Maintenance on Cohesive Sediment Transport in Gezira Scheme, Sudan." Leiden, The Netherlands.

Owain, Erin Llwyd, and Mark Andrew Maslin. 2018. "Assessing the Relative Contribution of Economic, Political and Environmental Factors on Past Conflict and the Displacement of People in East Africa." *Humanities & Social Sciences Communications* 4: 47.

Pesaran M. Hashem, Yongcheol Shin, and Rcihard J. Smith. 2001. "Bounds Testing Approaches to the Analysis of Level Relationships." *Journal of Applied Econometrics* 16: 289–326.

Rao, I. V. Y. Rama. 2012. "Efficiency, Yield Gap and Constraints Analysis in Irrigated vis-à-vis Rainfed Sugarcane in North Coastal Zone of Andhra Pradesh." *Agriculture Economics Research Review* 25 (1): 167–71.

Reuveny, Rafael. 2007. "Climate Change-Induced Migration and Violent Conflict." *Political Geography* 26 (6): 656–73.

Regional Food Security Analysis Network. 2016. "The Impact of ISIS on Iraq's Agriculture Sector." Jordan.

Rehman, Sidra. Forthcoming. "Weathering the Storm: The Impact of Climate Shocks on Conflict Intensity." IMF Working Paper, International Monetary Fund, Washington, DC.

Russ, Jason. 2020. "Water Runoff and Economic Activity: The Impact of Water Supply Shocks on Growth." *Journal of Environmental Economics and Management* 101: 102322.

Scartozzi, Cesare M. 2021. "Reframing Climate-Induced Socio-Environmental Conflicts: A Systematic Review." *International Studies Review* 23 (3): 696–725.

Schleussner, Carl-Friedrich, Tabea K. Lissner, Erich M. Fischer, Jan Wohland, Mahé Perrette, Antonius Golly, Joeri Rogelj, Katelin Childers, Jacob Schewe, Katja Frieler, Matthias Mengel, William Hare, and Michiel Schaeffer. 2016. "Differential Climate Impacts for Policy-Relevant Limits to Global Warming: The Case of 1.5°C and 2°C." *Earth System Dynamics* 7: 327–51.

Signé, Landry, and Ahmadou Aly Mbaye. 2022. "Renewing Global Climate Change Action for Fragile and Developing Countries." Global Economy and Development Working Paper 179, Brookings, Washington, DC.

Taylor, Charles A. 2022. "Irrigation and Climate Change: Long-run Adaptation and Its Externalities." NBER Conference on American Agriculture, Water Resources, and Climate Change, May 12–13.

Theisen, Ole Magnus, Helge Holtermann, and Halvard Buhaug. 2012. "Climate Wars? Assessing the Claim that Drought Breeds Conflict." *International Security* 36 (3): 79–106.

Theriault, Veronique, Melinda Smale, and Hamza Haider. 2017. "Maize Yield Response to Fertilizer under Differing Agro-Ecological Conditions in Burkina Faso." MSU International Development Working Paper 155, Michigan State University, East Lansing, MI.

Tintchev, Kalin. Forthcoming. "Long-term Macroeconomic Effects of Drought in Fragile States." IMF Working Paper, International Monetary Fund, Washington, DC.

Tombe, Erneo Balasio Peter. 2019. "South Sudan: Eastern Nile Irrigation System Performance Assessment and Option for Improvement." Nile Basin Initiative, Entebbe, Uganda.

Tufa, Kebede Nanesa. 2021. "Review on Status, Opportunities and Challenges of Irrigation Practices in Awash River Basin, Ethiopia." *Agrotechnology* 10 (4).

United Nations. 2018. "The Global Compact on Refugees." New York.

UN Environment Programme. 2021. "Adaptation Gap Report 2020." Nairobi.

United Nations Framework Convention on Climate Change. 2012. "Slow Onset Events." TP/2012/7

Vesco, Paola, Matija Kovacic, Malcolm Mistry, and Mihai. Croicu, 2021. "Climate Variability, Crop and Conflict: Exploring the Impacts of Spatial Concentration in Agricultural Production." *Journal of Peace Research* 58 (1): 98–113.

Vicente-Serrano, Sergio M., Santiago Beguería, and Juan I. López-Moren. 2010. "A Multiscalar Drought Index Sensitive to Global Warming: The Standardized Precipitation Evapotranspiration Index." *Journal of Climate* 23 (7): 1696–1718.

Von Uexkull, Nina, Mihai Croicu, Hanne Fjelde, and Halvard Buhaug. 2016. "Civil Conflict Sensitivity to Growing-Season Drought." *PNAS* 113 (44): 12391–96.

Wischnath, Gerdis, and Halvard Buhaug. 2014. "On Climate Variability and Civil War in Asia." *Climatic Change* 122 (4): 709–21.

World Bank. 2016. "Project Paper on Emergency Resilience Recovery Project in Mozambique." Report PAD2115, Washington, DC.

World Bank. 2018. "Democratic Republic of Congo Urbanization Review," Washington, DC.

World Bank. 2019. "Kinshasa Multisector Development and Urban Resilience Project: Project Implementation Document." Washington, DC.

World Bank. 2020. "Where Climate Change Is Reality: Supporting Africa's Sahel Pastoralists to Secure a Resilient Future." Washington, DC.

World Bank. 2021. "Future of Food: Building Stronger Food Systems in Fragility, Conflict, and Violence Settings." Washington, DC.

World Bank. 2022. "Enhancing Government Effectiveness and Transparency: The Fight Against Corruption." Washington, DC.

World Bank. 2023. "World Development Report 2023: Migrants, Refugees, and Societies." Washington, DC.

Zaveri, Esha D., Richard Damania, and Nathan Engle. 2023. "Droughts and Deficits: The Global Impact of Droughts on Economic Growth." World Bank Policy Research Working Paper 10453, World Bank, Washinton, DC.

PUBLICATIONS

Climate Challenges in Fragile and Conflict-Affected States

IMF STAFF CLIMATE NOTE 2023/001

ISBN 979-8-4002-5208-2
9 798400 252082