NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

DAMPENING EFFECTS OF FOOD IMPORTATION ON CLIMATE CHANGE–INDUCED CONFLICT IN AFRICA

by

Anthony S. Loden

December 2017

Thesis Advisor:	Emily Meierding
Second Reader:	Gregory van der Vink

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REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC 20503.			
1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** December 2017	**3. REPORT TYPE AND DATES COVERED** Master's thesis	
4. TITLE AND SUBTITLE DAMPENING EFFECTS OF FOOD IMPORTATION ON CLIMATE CHANGE–INDUCED CONFLICT IN AFRICA			**5. FUNDING NUMBERS**
6. AUTHOR(S) Anthony S. Loden			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING / MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB number ____N/A____.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release. Distribution is unlimited.			**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200 words)

As the scientific community speaks in unison regarding mankind's role in climate change, the rhetoric over the potential security implications of a changing climate is much less coherent. This thesis investigates whether a country's dependence on foreign food imports and food aid alters the relationship between deviations in normal rainfall patterns and conflict in Africa. The results of this study indicate that (i) deviations in both previous year and contemporaneous rainfall significantly impact cereal supplies with previous year rainfall exhibiting a stronger correlative effect; (ii) countries that depend more heavily on cereal foods sourced from outside their borders display a lower risk of civil conflict during wetter than normal years and non-government-targeted social conflict during anomalously wet and dry years when compared to countries that produce the majority of their cereal supplies domestically; and (iii) the risk of violent, nonviolent, and government-targeted social conflict is greater following significant fluctuations in rainfall for the those countries that grow the majority of their own cereal. These findings suggest that mitigation strategies focused on improving water management, developing more efficient and stable import practices, and diversifying a country's food sourcing options may reduce the impact of climate change–induced conflict.

14. SUBJECT TERMS climate change, conflict, food security, import dependency			**15. NUMBER OF PAGES** 77
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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DAMPENING EFFECTS OF FOOD IMPORTATION ON CLIMATE CHANGE–INDUCED CONFLICT IN AFRICA

Anthony S. Loden
Captain, United States Air Force
A.B., Princeton University, 2000

Submitted in partial fulfillment of the
requirements for the degree of

**MASTER OF ARTS IN SECURITY STUDIES
(HOMELAND SECURITY AND DEFENSE)**

from the

**NAVAL POSTGRADUATE SCHOOL
December 2017**

Approved by: Emily Meierding
Thesis Advisor

Gregory van der Vink
Second Reader, Princeton University

Mohammed Hafez
Chair, Department of National Security Affairs

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ABSTRACT

As the scientific community speaks in unison regarding mankind's role in climate change, the rhetoric over the potential security implications of a changing climate is much less coherent. This thesis investigates whether a country's dependence on foreign food imports and food aid alters the relationship between deviations in normal rainfall patterns and conflict in Africa. The results of this study indicate that (i) deviations in both previous year and contemporaneous rainfall significantly impact cereal supplies with previous year rainfall exhibiting a stronger correlative effect; (ii) countries that depend more heavily on cereal foods sourced from outside their borders display a lower risk of civil conflict during wetter than normal years and non-government-targeted social conflict during anomalously wet and dry years when compared to countries that produce the majority of their cereal supplies domestically; and (iii) the risk of violent, nonviolent, and government-targeted social conflict is greater following significant fluctuations in rainfall for the those countries that grow the majority of their own cereal. These findings suggest that mitigation strategies focused on improving water management, developing more efficient and stable import practices, and diversifying a country's food sourcing options may reduce the impact of climate change–induced conflict.

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LIST OF ACRONYMS AND ABBREVIATIONS

AR5	Fifth Assessment Report
DOD	Department of Defense
FAO	Food and Agricultural Organization
FDR	foreign-source dependency ratio
GDP	gross domestic product
GPCP	Global Precipitation Climatology Project
IDR	import dependency ratio
IPCC	Intergovernmental Panel on Climate Change
PRIO	Peace Research Institute Oslo
SCAD	Social Conflict in Africa Database
UCDP	Uppsala Conflict Data Program

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ACKNOWLEDGMENTS

I would like to thank Professors Emily Meierding and Gregory van der Vink for their academic guidance and Sasan Mousavi for his editorial assistance.

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I. INTRODUCTION

A. MAJOR RESEARCH QUESTION

Does a country's (in)dependence on foreign food sources (imports and aid) influence the incidence of civil conflict following weather-related shocks to its water supply? Are countries that import or receive the majority of their food in aid somehow insulated from the negative effects of precipitation-related fluctuations in domestic agricultural production, and thus at a lower risk for social conflict, civil war, and insurgency? This thesis will examine the relationship between precipitation, food supply, dependence foreign food sources, and the onset of civil and social conflict in Africa immediately following significant deviations from normal rainfall patterns in both the positive and negative direction. As a baseline, this thesis will reevaluate a study conducted by Hendrix and Salehyan that examines the causal effect of precipitation shocks on various measures of conflict and attempts to strengthen their models by applying several additional control variables to test whether a country's level of dependence on foreign food imports and aid alters the potential adverse effects of climate change.[1]

B. SIGNIFICANCE OF THE RESEARCH QUESTION

As the scientific community continues to coalesce around a growing body of evidence indicating a direct anthropogenic link to climate change, international rhetoric, amongst policy makers in particular, regarding the potential security implications of a changing climate is, much like the atmosphere, gradually heating up. Oft-cited claims suggest that climate change (changes in average temperature, precipitation patterns, length of growing season, etc.) will have a catastrophic impact on global food supplies, economic production, and access to adequate drinking water. It is further argued that these climatically induced conditions, in conjunction with forced migrations associated

[1] Cullen S. Hendrix and Idean Salehyan. "Climate Change, Rainfall, and Social Conflict in Africa." *Journal of Peace Research* 49, no. 1 (2012): 35–50, https://doi.org/10.117 7/0022343311426165.

with rising sea levels and resource scarcity, will lead to increased levels of instability and violent conflict. Once regarded as alarmist prophecies along the same lines as Paul Ehrlich's best-selling yet highly criticized book *The Population Bomb*, these dire warnings have since percolated to the highest levels of government.[2] The United States Department of Defense (DOD), in particular, recognizes climate change as a significant threat to all three of what it believes are the most basic tenets of national and international security: defense, diplomacy, and economics.[3] In 2011, the DOD issued a comprehensive report outlining the potential global implications of climate change with a special focus on Africa and in 2014, then Secretary of Defense Chuck Hagel warned that

> Rising global temperatures, changing precipitation patterns, climbing sea levels, and more extreme weather events will intensify the challenges of global instability, hunger, poverty, and conflict. They will likely lead to food and water shortages, pandemic disease, disputes over refugees and resources, and destruction by natural disasters in regions across the globe.[4]

Subsequently, the most recent National Security Strategy (2015) issued by the White House identified climate change as an "urgent and growing threat" to national security.[5]

Simultaneously, apocalyptic scenarios involving potential "climate wars" have led to several bold predictions within the academic community. Most notable, perhaps, is a 2009 estimate by Marshal Burke et al. projecting an additional 393,000 battle deaths by 2030 due to global warming.[6] Compounding these ominous predictions even further is a recent *New York* magazine article that suggests these climate wars will erupt "sooner than

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[2] Paul Ehrlich, *The Population Bomb* (New York, NY: Ballantine Books, 1968).

[3] U.S. Department of Defense, *Trends and Implications of Climate Change for National and International Security* (Washington, DC: Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, October 2011), xii.

[4] U.S. Department of Defense, *Climate Change Adaptation Roadmap* (Alexandria, VA: Office of the Assistant Secretary of Defense (Energy, Installations, and Environment) Environment, Safety & Occupational Health Directorate, June 2014): Foreword; DOD, *Trends and Implications of Climate Change for National and International Security*.

[5] Barack H. Obama, *National Security Strategy* (Washington, DC: The White House, February, 2015): 12.

[6] Marshall B. Burke et al., "Warming Increases the Risk of Civil War in Africa," *Proceedings of the National Academy of Sciences of the United States of America* 106, no. 49 (December 8, 2009): 20670, www.pnas.org/cgi/doi/10.1073/pnas.0907998106.

you think."[7] Humans, however, do not freely resort to violence, as Halvard Buhaug notes, simply because "temperature heats up or rainfall comes in unexpected ways."[8] The effects of climate change on global unrest are much more likely to be indirect and, therefore, must be examined with a more disaggregated approach to flush out intermediate causal links connecting climate change to the outbreak of conflict.[9]

Much of the current research examining the potential links between climate change and conflict focuses on whether deviations from annual mean temperature and precipitation rates impact the availability of critical resources. Food security related issues, in particular, have garnered considerable attention as potential precursors to conflict due to the direct dependence of agricultural production on weather conditions. Unfortunately, if such a causal connection exists, the time horizon for reversing current climate trends will, at best, be measured in terms of decades or, worse yet, centuries. As such, the ability to diagnose the intermediate linkages between the manifestation of climate change and the onset of conflict will assist in identifying those populations most vulnerable to climate change-induced conflict. Early detection, in turn, will allow for the timely implementation of cost effective, and politically tenable intervention plans designed to increase resilience among the most vulnerable populations.

Due to its relatively high rates of conflict and a wide range of social, political, and economic conditions conducive to civil war and lower levels of social contention, Africa's perceived vulnerability to climate change is often the focal point for an extensive cross section of the ongoing climate change-conflict research.[10] One of the primary risk factors besieging the continent is the fact that large segments of the African population,

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7 David Wallace Wells, "The Uninhabitable Earth," *New York Magazine*, July 9, 2017, http://nymag.com/daily/intelligencer/2017/07/climate-change-earth-too-hot-for-humans.html. For examples of "climate wars" see Gwynne Dyer, *Climate Wars* (Canada: Random House, 2008); Harald Welzer, *Climate Wars: What People Will Be Killed for in the 21st Century* (Cambridge: Polity Press, 2012).

8 Halvard Buhaug, "Climate Change and Conflict: Taking Stock," *Peace Economics, Peace Science, & Public Policy* 22, no. 4 (December 2016): 333.

9 Emily Meierding, "Climate Change and Conflict: Avoiding the Small Talk about the Weather," *International Studies Review* 15, no. 2 (June 2013): 194, http://dx.doi.org/10.1111/misr.12030.

10 Ole Magnus Theisen, Helge Holtermann, and Halvard Buhaug, "Climate Wars? Assessing the Claim That Drought Breeds Conflict," *International Security* 36, no. 3 (2011): 102–104, http://www.jstor.org/stable/41428110.

as much 60 percent of the workforce, remain dependent upon agricultural production, rain-fed agriculture in particular, for their livelihoods.[11] Unfortunately, an extensive body of research compiled by the United Nations Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5) predicts that current trends in climate change will severely alter precipitation patterns throughout the African continent.[12] Reductions in rainfall are projected for both northern and southern Africa, wetter conditions are expected over much of west Africa, while eastern Africa, on a whole, is forecast to experience increases in rainfall with several sub-regional areas projected to undergo drier conditions. Extreme rainfall deviations, including more frequent episodes of drought and inundation, are also projected to increase with regional variation. As it stands, the African continent will be one of the areas most directly impacted by climate change and, therefore, most at risk for climate change induced conflict, should a connection exist.

The following chapters of this thesis will begin with a review of the current literature addressing potential links between climate change and the onset of conflict with a particular focus on precipitation and food security. Chapter III will develop a theory of how a dependence on food from foreign sources may mitigate the effects of significant deviations from normal rainfall patterns at the country level on the onset of conflict, which the discussed body of literature will propose. Chapter IV will outline the data and methodology utilized in the analysis followed by a presentation of the results. The final chapter will offer a brief discussion on the potential implications of these findings.

[11] Nienke M. Beintema and Gert-Jan Stads, "Sub-Saharan African Agricultural Research— Recent Investment Trends," *Outlook on Agriculture* 33, no. 4 (2004): 239–246, https://doi.org/10.5367/0000000042664774; Isabelle Niang et al., "Africa," in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. Vincente R. Barros et al. (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, 2014): 1209–12011.

[12] Niang et al., "Africa", 1218.

II. LITERATURE REVIEW

A. EMERGENCE OF ENVIRONMENTAL SECURITY

There is an almost universal agreement among scientists that anthropomorphic contributions to greenhouse gases are accelerating the rate of global climate change.[13] There is, however, less of a consensus regarding what the overall implications of a changing climate are when viewed from a national security standpoint. Ullman provides one of the earliest works to argue that, in broad terms, environmental degradation could have a negative impact on national security and that sudden shocks to resource supplies are particularly disruptive.[14] Several years later, the 42nd United Nations General Assembly (1987) introduced a number of resolutions tied to the concept of environmental security with warnings of unprecedented "suffering, economic losses and social disruption."[15]

Pioneered in large part by the Thomas Homer-Dixon led Project on Environment, Population, and Security, this emerging field of environmental security narrowed over the following decade around the belief that environmental changes could spark violent conflict. In particular, Homer-Dixon and colleagues argued that environmental stresses leading to resource scarcity increase the risk of internal conflict when quality of life is

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13 IPCC, *Climate Change 2014: Synthesis Report*. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Geneva, Switzerland: IPCC, 2014): v.

14 Richard Ullman, "Redefining Security," *International Security* 8, no. 1 (1983): 134–146, http://www.jstor.org/stable/2538489; Cullen S. Hendrix and Sarah M. Glaser, "Trends and Triggers: Climate, Climate Change and Civil Conflict in Sub-Saharan Africa," *Political Geography* 26, no. 6 (August 2007): 696, http://dx.doi.org/10.1016/j.polgeo.2007.06.006.

For additional early research regarding resource scarcity see Ruth W. Arad and Uzi B. Arad, "Scarce Natural Resources and Potential Conflict," in *Sharing Global Resources* ed. Ruth W. Arad (New York: McGraw-Hill, 1979): 23–104; Jessica T. Mathews, "Redefining Security," *Foreign Affairs* 68, no. 2 (Spring 1989): 162–177, https://www.foreignaffairs.com/articles/1989-03-01/redefining-security.

15 United Nations General Assembly, Resolutions A/RES/42/189A-D, *Implementation of the Plan of Action to Combat Desertification*, (December 11, 1987), http://www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/42/189.

impacted.[16] At the time, the proposed origins of these environmental stresses were more neo-Malthusian than climate-related and categorized into three overarching subsets: supply-induced, demand-induced, and structural (maldistribution).[17]

Critiques of Homer-Dixon's models argued that the causal chains presented were too complex and, therefore, precluded clear identification of environmental degradation as a determinant source of conflict.[18] In addition, although referenced in general terms, there was an overall lack of systematic analysis applied to control for a mix of political, economic, and cultural variables. Additionally, distinctions between environmentally induced scarcity and societal mismanagement of resources were absent, blurring the climate change-conflict connection.

B. THE CLIMATE CHANGE-CONFLICT DEBATE

Over the past 10–15 years, climate change has replaced population growth and more general environmental degradation (toxic waste, water pollution, deforestation, etc.) as the primary focus within much of the environmental security literature.[19] In addition to Burke et al.'s doomsday estimate of over a third of a million climate change-related battle deaths, there are a number of empirical studies that suggest a direct causal link between

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16 Thomas Homer-Dixon, "On the Threshold: Environmental Changes as Causes of Acute Conflict," *International Security* 16, no. 2 (Fall 1991): 76–116, http://www.jstor.org/stable/2539061; Thomas Homer-Dixon, "Environmental Scarcities and Violent Conflict: Evidence from Cases," *International Security* 19, no. 1 (Summer 1994): 5–40, http://www.jstor.org/stable/2539147; Thomas Homer-Dixon, *Environment, Scarcity, and Violence* (Princeton, NJ: Princeton University Press, 1999).

17 Valerie Percival and Thomas Homer-Dixon, "Environmental Scarcity and Violent Conflict: The Case of South Africa," *Journal of Peace Research* 35, no. 3 (1998): 282–285, https://doi.org/10.1177%2F0022343398035003002; Thomas Homer-Dixon and Jessica Blitt, *Ecoviolence: Links among Environment, Population, and Security* (Lanham, MD: Rowman and Littlefield, 1998), 5–7.

18 Nils Peter Gleditsch, "Armed Conflict and the Environment: A Critique of the Literature," *Journal of Peace Research* 35, no. 3 (May 1998): 381–400, http://www.jstor.org/stable/424942.

19 Meierding, "Climate Change and Conflict," 185–203.

climate change and increasing levels of conflict.[20] Although more systematic in their analysis than previous works, including efforts to apply meaningful controls, the bulk of these large-N analyses are challenged by an opposing collection of quantitative studies that find no significant link between climate change and conflict.[21] Koubi et al. and van Weezel find that reductions in economic growth as a result of climate variability do not appear to have a significant impact on conflict, while Schleussner et al. suggest that, although climate related disasters are not robustly associated as direct triggers for conflict on a global scale, these disruptive conditions have a greater propensity to dissolve into violence when they occur in ethnically fractionalized societies.[22] Muddying the waters further are suggestions that global warming could actually coincide with a reduction in conflict, as the economic development typically associated with contributing to increased greenhouse gas emissions also serves to encourage interstate peace.[23] This lack of consensus is, perhaps, most evident in the ongoing debate between two research camps led primarily by Burke, Solomon Hsiang, and Edward Miguel (robust causal links) and

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20 In addition to Burke et al., "Warming Increases the Risk of Civil War" see Hanne Fjelde and Nina von Uexkull, "Climate Triggers: Rainfall Anomalies, Vulnerability and Communal Conflict in Sub-Saharan Africa." *Political Geography* 31, no. 7 (September 2012): 444–453, https://doi.org/10.1016/j.polgeo.2012.08.004. doi:http://dx.doi.org/10.1016/j.polgeo.2012.08.004; Hendrix and Salehyan, "Climate Change, Rainfall, and Social Conflict in Africa," 35–50; Clionadh Raleigh and Dominic Kniveton, "Come Rain Or Shine: An Analysis of Conflict and Climate Variability in East Africa," *Journal of Peace Research* 49, no. 1 (2012): 51–64, http://dx.doi.org/10.1177/0022343311427754.

21 Mathieu Couttenier and Raphael Soubeyran, "Drought and Civil War in Sub-Saharan Africa," *The Economic Journal* 124, no. 575 (March 2014): 201, http://dx.doi.org/10.1111/ecoj.12042; Rune T. Slettebak, "Don't Blame the Weather! Climate-Related Natural Disasters and Civil Conflict," *Journal of Peace Research* 49, no. 1 (2012): 163, https://doi.org/10.1177/0022343311425693; Ole Magnus Theisen, "Climate Clashes? Weather Variability, Land Pressure, and Organized Violence in Kenya, 1989–2004," *Journal of Peace Research* 49, no. 1 (2012): 81–96, doi:http://dx.doi.org/10.1177/0022343311425842.

22 Vally Koubi et al., "Climate Variability, Economic Growth, and Civil Conflict," *Journal of Peace Research* 49, no. 1 (2012): 124, https://doi.org/10.1177/0022343311427173; Stijn van Weezel, "Economic Shocks & Civil Conflict Onset in Sub-Saharan Africa, 1981–2010," *Defense and Peace Economics* 26, no. 2 (2015): 153, http://dx.doi.org/10.1080/10242694.2014.887489; Carl-Friedrich Schleussner et al., "Armed-Conflict Risks Enhanced by Climate-Related Disasters in Ethnically Fractionalized Countries," *Proceedings of the National Academy of Sciences of the United States of America* 113, no. 33 (August 16, 2016): 9216, http://dx.doi.org/10.1073/pnas.1601611113.

23 Erik Gartzke, "Could Climate Change Precipitate Peace," *Journal of Peace Research* 49, no. 1 (2012): 177–192, doi:http://dx.doi.org/10.1177/0022343311427342.

Buhaug (weak or absent causal links), who report opposing conclusions when examining similar data sets and empirical studies.[24]

Congruent with the aforementioned divergent opinions emanating from the broader climate change-conflict literature as a whole, the observed effects of rainfall as an individual influencer on conflict also lack a consensus. Fjelde and Uexkall find that, for Sub-Saharan Africa, communal conflict is more likely during anomalously dry years. Analyses by Theisen and Hendrix and Salehyan, on the other hand, show that civil conflict (i.e., armed conflict in which one side is represented by the government to include civil war and insurgency) occurs more frequently during wetter than normal years and hypothesize that extreme resource scarcity associated with severe droughts limit the mobilization efforts required to sustain large-scale violence.[25] Similar arguments that wetter conditions beget violence can be found in Adano et al., Butler and Gates, and Witsenburg and Adano; the latter of whom find that, contrary to resource scarcity theory, pastoralists are more likely to engage in violent livestock raiding during periods of relative abundance while cooperating when water is limited.[26] Conversely, Ember et al. contend that the relationship between precipitation and pastoral violence is negatively correlated. Hendrix and Salehyan find increased levels of social conflict in years exhibiting extreme rainfall deviations in both directions—drought and inundation.[27]

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24 Burke et al., "Warming Increases the Risk of Civil War"; Halvard Buhaug, "Climate Not to Blame for African Civil Wars," *Proceedings of the National Academy of Sciences of the United States of America* 107, no. 38 (September 21, 2010): 16477-16482, http://dx.doi.org/10.1073/pnas.1005739107; Solomon M. Hsiang and Kyle C. Meng, "Reconciling Disagreement Over Climate-Conflict Results in Africa," *Proceedings of the National Academy of Sciences of the United States of America* 111, no. 6 (2014): 2100, http://dx.doi.org/10.1073/pnas.1316006111; Halvard Buhaug et al., "One Effect to Rule Them All? A Comment on Climate and Conflict," *Climatic Change* 127, no. 3–4 (December 2014): 391–397. https://doi.org/10.1007/s10584-014-1266-1; Marshall Burke, Solomon M. Hsiang, and Edward Miguel, "Climate and Conflict," *Annual Review of Economics* 7, (2015): 577–617, https://doi.org/10.1146/annurev-economics-080614-115430.

25 Fjelde and Uexkall, "Climate Triggers," 452; Hendrix and Salehyan, "Climate Change, Rainfall, and Social Conflict in Africa," 46.

26 Wario R. Adano et al., "Climate Change, Violent Conflict and Local Institutions in Kenya's Drylands," *Journal of Peace Research* 49, no. 1 (2012): 77, http://dx.doi.org/10.1177/0022343311427344; Christopher K. Butler and Scott Gates, "African Range Wars: Climate, Conflict, and Property Rights," *Journal of Peace Research* 49, no. 1 (2012): 30–32, http://dx.doi.org/10.1177/0022343311426166; Karen M. Witsenburg and Wario R. Adano, "Of Rain and Raids: Violent Livestock Raiding in Northern Kenya," *Civil Wars* 11, no. 4 (December 2009): 536, http://dx.doi.org/10.1080/13698240903403915.

27 Hendrix and Salehyan, "Climate Change, Rainfall, and Social Conflict in Africa," 44.

Raleigh and Kniveton link higher rates of rebel conflict during both drier conditions and increased communal conflict during anomalously wet conditions.[28] Suggestions regarding the potential source for the conflicting nature of these findings include disagreements over climate versus weather, varying definitions of conflict, geographic scales, temporal lags, and meta-analysis approaches as the likely root causes for the ongoing disparity within the climate change-conflict research.[29]

C. FOOD SECURITY AND CONFLICT

One strategy to overcome the inconsistencies within the analytic framework of the aforementioned body of research is to apply a multi-stage approach to identify the intermediate social, political, and economic linkages that allow for meteorological indicators such as temperature and precipitation to influence the onset or severity of conflict.[30] In a return to Homer-Dixon's theory of resource scarcity, research concerning food insecurity as a potential driver of conflict is beginning to accumulate. Reductions in crop yields as a result of changing precipitation patterns can influence food access both directly, in terms of food available for consumption, and indirectly due to the web of factors that influence food prices and purchasing power in response to lost wages.[31] Several studies indicate that countries exhibiting poor health and nutrition display higher

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28 Carol R. Ember et al., "Livestock Raiding and Rainfall Variability in Northwestern Kenya," *Civil Wars* 14, no. 2 (June 2012): 159, http://dx.doi.org/10.1080/13698249.2012.679497; Raleigh and Kniveton, "Come Rain Or Shine," 51.

29 Thomas Bernauer, Tobias Böhmelt, and Vally Koubi, "Environmental Changes and Violent Conflict," *Environmental Research Letters* 7, no. 1 (2012): 1-6, http://dx.doi.org/10.1088/1748-9326/7/1/015601; Nils Petter Gleditsch, "Whither the Weather? Climate Change and Conflict," *Journal of Peace Research* 49, no. 1 (2012): 3–9, https://doi.org/10.1177/0022343311431288; Meierding, "Climate Change and Conflict," 189–191; Idean Salehyan, "Climate Change and Conflict: Making Sense of Disparate Findings," *Political Geography* 43 (November 2014): 1–5, http://dx.doi.org/10.1016/j.polgeo.2014.10.004; Juergen Scheffran et al., "Climate Change and Violent Conflict," *Science* 336, (May 18, 2012): 869–871, https://doi.org/10.1126/science.1221339.

30 Meierding, "Climate Change and Conflict," 189; Buhaug, "Climate Change and Conflict," 334.

31 Michael Oppenheimer et al., "Emergent Risks and Key Vulnerabilities" in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. Vincente R. Barros et al. (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, 2014): 1059–1060.

frequencies of civil conflict.[32] In addition, low levels of caloric intake per capita are also linked to an increased likelihood of democratic breakdowns within emerging democracies, which, in turn, has the potential to affect civil conflict given that non-democratic states display higher rates of civil war deaths.[33] Exacerbating these potential links is a study by Raleigh, Choi, and Kniveton that suggests food security and violence are intertwined in a positive feedback loop wherein rising food prices lead to increased violent conflict; the effects of which, in turn, cause food prices to rise even further.[34] Although the exact pathway from precipitation to food security/insecurity to conflict is complex, explanations addressing the broader mechanisms driving this relationship typically fall into on one of two contrasting narratives—scarcity versus abundance—depending on the observed sign of the rainfall deviation.

When examining a food dependent causal pathway, Homer-Dixon's resource scarcity theory is, perhaps, the most frequently applied model within the current climate change-conflict research for articulating how drier than normal conditions lead to elevated levels of lower forms of political and social conflict, such as protests, riots, strikes, and communal violence.[35] This 'zero-sum' narrative suggests that drought conditions reduce agricultural production leading to intense competition over increasingly scarce or more expensive food supplies whereby individuals or groups may

32 Per Pinstrup-Andersen and Satoru Shimokawa, "Do Poverty and Poor Health and Nutrition Increase the Risk of Armed Conflict Onset?," *Food Policy* 33, no. 6 (December 2008): 513–520, http://dx.doi.org/10.1016/j.foodpol.2008.05.003; Henk-Jan Brinkman and Cullen S. Hendrix, "Food Insecurity and Violent Conflict: Causes, Consequences, and Addressing the Challenges," *World Food Programme Occasional Paper* 24, (2011): 5-10, http:// documents.wfp.org/stellent/groups/public/documents/ newsroom/wfp238358.pdf.

33 Bethany Lacina, "Explaining the Severity of Civil Wars," *Journal of Conflict Resolution* 50, no. 2 (2006): 276, http://dx.doi.org/10.1177/0022002705284828; Christopher Reenock, Michael Bernhard, and David Sobek, "Regressive Socioeconomic Distribution and Democratic Survival," *International Studies Quarterly* 51, no. 3 (September 2007): 693–694, http://www.jstor.org/stable/4621733.

34 Clionadh Raleigh, Hyun Jin Choi, and Dominc Kniveton, "The Devil is in the Details: An Investigation of the Relationships Between Conflict, Food Price and Climate Across Africa," *Global Environmental Change* 32 (2015): 187, http://dx.doi/10.1016/j.gloenvcha.2015.03.005.

35 Hendrix and Salehyan, "Climate Change, Rainfall, and Social Conflict in Africa," 45–56; Raleigh and Kniveton, "Come Rain Or Shine," 54.

eventually become desperate and, subsequently, resort to the use of force.[36] Although less intuitive, this pathway is sometimes also proposed for extremely wet conditions due to a combination of reduced crop yields as a result of flooding and limited distribution capacities as unpaved roads linking more rural agricultural regions with net-purchasing urban populations become impassible.[37]

Wischnath and Buhaug propose three complementary processes connecting reduced agricultural production to conflict: lowered opportunity costs, increased recruitment pools, and more widespread social grievances.[38] The crux of this theory suggests that when adequate food supplies are available, the opportunity costs of taking up arms against the government remain relatively high.[39] When reductions in agricultural and pastoral production lead to higher food prices and lost incomes, these opportunity costs may begin to drop. Once an individual's basic needs are no longer met through legal means his or her participation in contentious behavior becomes more economically advantageous.[40] At the same time, reductions in agricultural-based tax revenues leave governments less able to meet the growing entitlement needs of a hungry population.[41] Additionally, shocks to the agriculture sector often lead to high levels of unemployment for young, uneducated men in rural areas who, unfortunately, comprise the same

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36 John W. Maxwell and Rafael Reuveny, "Resource Scarcity and Conflict in Developing Countries," *Journal of Peace and Research* 37, no. 3 (2000): 303–304, https://doi.org/10.1177/0022343300037003002; Raleigh, Choi, and Kniveton, "The Devil is in the Details," 188; Raleigh and Kniveton, "Come Rain Or Shine," 54.

37 Hendrix and Salehyan, "Climate Change, Rainfall, and Social Conflict in Africa," 37.

38 Gerdis Wischnath and Halvard Buhaug, "Rice or Riots: On Food Production and Conflict Severity Across India," *Political Geography* 43 (November 2014): 6–15, https://doi.org/10.1016/j.polgeo.2014.07.004.

39 Paul Collier and Anke Hoeffler, "Greed and Grievance in Civil War," *Oxford Economic Papers* 56, no. 4 (October 2004): 563–595, https://doi.org/10.1093/oep/gpf064.

40 Hanne Fjelde, "Farming or Fighting? Agricultural Price Shocks and Civil War in Africa," *World Development* 67 (2015): 525–34, https://doi.org/10.1016/j.worlddev.2014.10.032; Edward Miguel, Shanker Satyanath and Ernest Sergenti, "Economic Shocks and Civil Conflict: an Instrumental Variables Approach," *Journal of Political Economy* 112, no. 4 (2004): 725–53, http://dx.doi.org/10.1086/421174.

41 Hendrix and Salehyan (2012), 38.

demographic as those most likely to become potential combatants.[42] Furthermore, mismanagement of relief aid due to a combination of weak governance and diminishing capacity, whether real or perceived, exacerbate the level of grievances against the state, an important factor in social mobilization theory.[43] Evidence for the scarcity relationship is found in studies linking increased conflict in the wake of reduced rice yields in both India and Indonesia.[44] For lower levels of political and social conflict, such as protests, riots, strikes, and communal violence, the relationship is more curvilinear with precipitation shocks on both ends of the spectrum (high and low rainfall) increasing the likelihood of conflict.[45] Additional research utilizing food prices as a proxy for food scarcity link rising food prices and increases in conflict with several studies suggesting that the 2011 Arab Spring was sparked, at least in part, by international spikes in food prices.[46] The validity of those claims, however, remains in question.[47]

Abundance theory, on the other hand, relies on a similar cost-benefit calculation but operates in the opposite direction. Positive shocks to the water supply (above average rainfall) can enhance agricultural productivity which, in turn, may increase rent-seeking behavior, provide the necessary resources to recruit and fund insurgencies, and lead to

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42 Brinkman and Hendrix (2011), 6; Henrik Urdal, "A Clash of Generations? Youth Bulges and Political Violence," *International Studies Quarterly* 50, no. 3 (September 2006): 607–629, http://dx.doi.org/10.1111/j.1468-2478.2006.00416.x.

43 David Sobek and Charles Boehmer, "If They Only Had Cake: The Effect of Food Supply on Civil War Onset," 1960–1999," Unpublished manuscript: 12; Sidney Tarrow, *Power in Movement: Social Movements and Contentious Politics* (New York: Cambridge University Press, 2006), 14.

44 Raul Caruso, Ilaria Petrarca, and Roberto Ricciuti, "Climate Change, Rice Crops, and Violence: Evidence from Indonesia," *Journal of Peace Research* 53, no. 1 (2016): 66, https://doi.org/10.1177/0022343315616061; Wischnath and Buhaug, "Rice or Riots," 6.

45 Hendrix and Salehyan, "Climate Change, Rainfall, and Social Conflict in Africa," 45–56; Raleigh and Kniveton, "Come Rain Or Shine," 62.

46 Annia Ciezadlo, "Let Them Eat Bread," *Foreign Affairs*, March 23, 2001, https://www.foreignaffairs.com/articles/tunisia/2011-03-23/let-them-eat-bread; Sarah Johnstone and Jeffrey Mazo, "Global Warming and the Arab Spring," *Survival: Global Politics Strategy* 53 (2011): 11–17, http://dx.doi.org/10.1080/00396338.2011.571006; Raleigh, Choi, and Kniveton, "The Devil is in the Details," 187; Todd Graham Smith, "Feeding Unrest: Disentangling the Causal Relationship Between Food Price Shocks and Sociopolitical Conflict in Urban Africa," *Journal of Peace Research* 51, no. 6 (2014), 679–695, https://doi.org/10.1177/0022343314543722; Troy Sternberg, "Chinese Drought, Bread and the Arab Spring," *Applied Geography* 34 (May 2012): 519–524, https://doi.org/10.1016/j.apgeog.2012.02.004.

47 Smith, "Feeding Unrest," 681–682.

disagreements over the distribution of a commodity or its derivative wealth, all of which may increase the likelihood of one or more sides engaging in violent or contentious behavior increases.[48] Additionally, the potential gains associated with theft and looting increase as wealth increases.[49] Overall, increased agricultural production may shift the opportunity costs in favor of participating in violent activities while simultaneously providing the necessary means to sustain resource intensive activities such as civil war and insurgency.[50] As Napoléon once suggested, "an army marches on its stomach."[51] In line with this rationale, several studies examining the connection between deviations to long term precipitation patterns and the onset of civil conflict indicate that wetter than normal years are more likely to increase the probability of civil conflict.[52]

D. POTENTIAL IMPACTS OF CLIMATE CHANGE ON AGRICULTURAL PRODUCTION IN AFRICA

Climate change-induced fluctuations in precipitation are likely to have a significant impact on the Africa's overall agricultural sector. Inadequate water storage and irrigation infrastructure leave 95 percent of the continent's agricultural production dependent upon direct rainfall.[53] The IPCC AR5 reports with high confidence that current

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48 Paul Collier and Anke Hoeffler, "Resource Rents, Governance, and Conflict," *Journal of Conflict Resolution* 49, no. 4 (2005): 625–633, https://doi.org/10.1177/0022002705277551; Macartan Humphreys, "Natural Resources, Conflict, and Conflict Resolution," *Journal of Conflict Resolution* 49, no. 4: 508–537, https://doi.org/10.1177/0022002705277545; Cullen Hendrix, "Measuring State Capacity: Theoretical and Empirical Implications for the Study of Conflict," *Journal of Peace Research* 47, no. 3 (2010): 273–285, https://doi.org/10.1177/0022343310361838; Raleigh, Choi, and Kniveton, "The Devil is in the Details,"188; Raleigh and Kniveton, "Come Rain or Shine," 54; Katharina Wick and Erwin H. Bulte, "Contesting Resources: Rent Seeking, Conflict and the Natural Resource Curse," *Public Choice* 128, no. 3/4 (September 2006): 457–476, http://www.jstor.org/stable/25487568.

49 Witsenburg and Adano, "Of Rain and Raids," 514.

50 Hendrix and Salehyan, "Climate Change, Rainfall, and Social Conflict in Africa," 36 and 45; Raleigh, Choi, and Kniveton, "The Devil is in the Details,"188–189.

51 "An army marches on its stomach," The Oxford Dictionary of Phrase and Fable, Encyclopedia.com, accessed October 13, 2017, http://www.encyclopedia.com/humanities/dictionaries-thesauruses-pictures-and-press-releases/army-marches-its-stomach.

52 Buhaug, "Climate Not to Blame," Model 7; Marshall Burke et al., "Climate and Civil War: Is the Relationship Robust," *NBER Working Paper* 16440, (October 2010): Table 3, Model 3, https://doi.org/10.3386/w16440; Hendrix and Salehyan, "Climate Change, Rainfall, and Social Conflict in Africa," 42–43.

53 DOD, *Trends and Implications of Climate Change for National and International Security*, xii.

climate change projections will have an overall negative impact on cereal crop yields over large sections of the Africa.[54] Maize production, for example, is expected to drop 18 percent over southern Africa by mid-century and wheat production could shrink by as much as 35 percent across the sub-Saharan region.[55] Likewise, suitable growing conditions for several high-value crops (coffee, tea, cocoa, and cotton) are expected to diminish.[56] The effects of climate change on other non-cereal crops range across the positive and negative spectrum depending on the particular crop and location.[57] With regards to livestock production, reductions in precipitation are likely to have a two-fold impact with drought conditions decreasing the availability of feed crops and, simultaneously, water supplies for animals as scarce water is redirected for crop irrigation.[58] Combined, the current body of research predicts the overall impact of climate change on agricultural production across much of Africa to be negative.[59]

The potential for reduced food production within the African continent is particularly alarming given that food insecurity is already a major problem for much of the population.[60] Household surveys estimate that as much as 59 percent of the population in 12 African countries is food insecure with more conservative estimates still hovering upwards of 39 percent.[61] The IPCC AR5 identifies food related issues in four of its nine climate change related key risk areas for Africa with medium to high risk estimated for all four.[62] These risks are further exacerbated by multiple institutional and

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54 Niang et al., "Africa," 1218.

55 Ibid., 1218.

56 Ibid., 1219.

57 Ibid., 1218–1219.

58 Ibid., 1219–1220.

59 John R. Porter et al., "Food Security and Food Production Systems," in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. Chris B. Field et al. (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, 2014): 488.

60 Food and Agricultural Organization of the United Nations, *Near East and North Africa Regional Overview of Food Insecurity 2016* Cairo: FAO, 2017: http://www.fao.org/3/a-i6860e.pdf.

61 Porter et al., "Food Security and Food Production Systems," 490.

62 Niang et al., "Africa," 1237–1238.

societal barriers that reduce the potential for the development and implementation of adaptive solutions to changing climates at the local and regional scale.[63]

[63] Ibid., 1236.

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III. THEORY AND HYPOTHESES

A. CONNECTING THE CONFLICT DOTS

Unfortunately, a fundamental evidence gap within the climate change-conflict debate persists with regards to connecting individual climatological factors with an assortment of proposed intermediate social, political, and economic linkages necessary to construct a more meaningful causal chain. A large swath of the current research discussed focuses primarily on establishing direct correlations between conflict and a slew of dependent variables located almost exclusively on the left-most or right-most end of the causal chain. On the left-most end are those studies that seek to establish a direct correlation between historic deviations in meteorological conditions and the onset of violent conflict. For example, it is often argued that, as noted above, an increased frequency of large fluctuations in precipitation due to climate change will, in turn, lead to more conflict. Likewise, studies focusing on the right-hand side of the causal chain highlight the role of food insecurity, a commonly proposed proxy for climate change, as a threat multiplier for the onset of conflict. There are, however, few meaningful attempts to flesh out the various indirect and interactive mechanisms occurring in between the meteorological variables on the left and the various indicators of food insecurity on the right that likely influence an environment of instability typically associated with the onset of conflict.

B. FOREIGN FOOD DEPENDENCE—A THREAT REDUCER?

Given the interconnected nature of precipitation and food production, there is a somewhat logical tendency to assume that the two phenomena are directly correlated. Likewise, the scarcity and abundance theories discussed in the previous chapter illustrate the logic behind a prevailing notion that climate change-induced fluctuations in the agricultural sector have the potential to drive societies toward conflict with food supply as a would-be vehicle. Piecing together the current literature suggests the following potential rudimentary causal pathway between climate change and conflict: significant deviations from long-term precipitation patterns lead to variations in agricultural production impacting food supplies, which, in turn, influences the propensity for individuals and groups to engage in contentious and violent behavior. If accurate, a confluence of tenuous social, political, economic, and environmental factors leaves much of Africa particularly vulnerable at virtually every stage along this causal chain.

This proposal, however, relies heavily on the presumption that a country's overall food supply is purely or, at the very least, predominantly dependent upon domestic food production and fails to take into account an individual country's ability and/or willingness to adjust import, export, and utilization practices in order to compensate for windfalls and shortfalls in production. Additionally, receipt of large foreign food aid, although problematic in its own right, may insulate a nation's overall food supply when faced with downturns in domestic production. Much of the climate change-conflict research tends to make the immediate leap from meteorological conditions, such as rainfall, to the onset of conflict with little or no consideration as to whether phenomena such as precipitation shocks have an actual effect on the overall supply of food within a given nation's borders. At the same time, studies examining food as a potential intermediate variable focus primarily on food prices—a metric that is often far more volatile than simple supply-demand curves might suggest.[64] Generally speaking, the bulk of the climate change-conflict research has yet to systematically account for the assorted methods individual countries employ to manage and secure their domestic food supplies—some of which are directly impacted by precipitation and some of which are not. Instead, they assume the correlation between rainfall and food supply is universal across both arid and damp climates. In order to apply either the resource scarcity theory or abundance theory to the above causal pathway, deviations in country's precipitation and food supply should coincide if one is to consider food as the presumptive resource affecting the incidence of conflict. As such, an initial hypothesis of this thesis is:

[64] Raleigh, Choi, and Kniveton, "The Devil is in the Details," 189–190; Smith, "Feeding Unrest," 679–682.

H1: Food supplies are directly linked to deviations in normal precipitation patterns with wetter than normal years yielding higher than normal food supplies and drier than normal years having the opposite effect.

Given the diverse economic and environmental conditions that exist across the African continent, it is highly unlikely that any climate change-food supply-conflict relationship will apply uniformly across both net food importers and net food producers alike. A country such as Algeria, for example, relies heavily on foreign imports to maintain its domestic food supply and is, consequently, one of the world's largest importers of wheat.[65] Although the relative impact on Algeria's domestic gross food production in the wake of a significant precipitation shock could just as easily mirror those felt by countries with more robust agricultural sectors, one would expect the resulting effect on Algeria's net food supply to be much lower given its domestic food production represents a relatively small portion of its overall food supply equation. A similar dampening effect should also hold when applied to the abundance theory of resource-derived conflict. Following better than average crop yields, the opportunity for rent-seeking behavior and increased resource pools to fund and supply insurgencies should remain comparatively low for import-dependent countries, such as Algeria, given that agriculture represents a relatively small portion of their overall economy.

Conversely, a nation such as Mali, which relies almost exclusively on domestic production for its supply of cereal-based foods, would appear to be at a much greater risk of suffering catastrophic food shortages in the wake of unfavorable growing conditions. Countries that are unaccustomed to relying on the large-scale importation of food may suffer from a lack of established international distribution chains, trade agreements, and foreign aid packages which, when combined with the additional transportation costs and delivery times associated with importing a commodity, as opposed to producing it at home, leave them less able to adapt and respond to sudden fluctuations in meteorological conditions.

[65] "Algeria - Agricultural Sector," International Trade Administration, U.S. Department of Commerce, last published June 15, 2016, https://www.export.gov/article?id=Algeria-Agricultural-Sector.

As such, one might expect the effects of deviations in normal precipitation patterns on the incidence of conflict to vary when controlling for disparities in each individual country's dependence of foreign food sources. By failing to account for these dissimilarities, there is a risk that the potential effects of climate change on the incidence of conflict will be understated for countries that are heavily dependent on domestic food production and overstated for those countries that rely more deeply on foreign sources to feed their populations. Attempts to apply a one-size-fits-all approach to mitigating the potential negative consequences of climate change will likely lead to the inefficient use of limited resources. The availability of financial capital is particularly scarce across the African continent with only four African nations maintaining a gross domestic product (GDP) per capita above than the global average.[66] Therefore, it is imperative that individual mitigation strategies are developed in order to address the specific vulnerabilities of each individual nation, food security for example, to ensure that intervention plans remain cost effective. Thus, the main hypothesis of this thesis is:

H2: Countries with a higher dependence on foreign food sources will exhibit a lower frequency of conflict directly following significant deviations in normal precipitation patterns.

[66] World Bank/World Development Indicators, (object name WDI (Excel)-ZIP; accessed on November 1, 2017), http://data.worldbank.org/data-catalog/world-development-indicators.

IV. DATA AND METHODS

A. PRECIPITATION AND CONFLICT REVISITED

In a study typical of the large-N analysis dominating much of the current climate change-conflict research, Hendrix and Salehyan examine the effects of precipitation shocks on the incidence of both civil war and social conflict on 47 African countries with populations greater than one million.[67] They find that extremely wet years increase the likelihood of civil conflict whereas both abnormally wet and dry years increase the risk of social conflict across Africa. This chapter reanalyzes their data controlling for the different methods a country uses to secure its food supply in order to test the resource scarcity and abundance theory based hypotheses presented in the previous chapter. The following analysis is conducted in two separate phases with the initial phase focused on Hypothesis 1, located along the left-hand side of the proposed causal chain. This preliminary phase examines whether extreme deviations from normal precipitation patterns actually alter the overall supply of food available within a given country. The second phase of analysis shifts further right along the causal chain to evaluate Hypothesis 2 in an attempt to determine whether a country's dependence on foreign food sources changes the overall risk of conflict in the wake of anomalously wet and dry years.

B. BASELINE DATA

1. Precipitation Data

For all models, Hendrix and Salehyan utilize the annual standardized rainfall deviation as their independent variable measured at the country level. To calculate this standardized deviation, the authors subtract the annual precipitation for a given country from its long-term (1979-2008) panel mean and then divide it by the standard deviation of that panel. Additionally, the authors include the squared term of the standardized deviation in their models as a test for potential curvilinear relationships. Lastly, their models also include lagged versions of both the linear and squared terms. Rainfall data is

[67] Hendrix and Salehyan, "Climate Change, Rainfall, and Social Conflict in Africa."

from the Global Precipitation Climatology Project (GPCP) database version 2.1 and is based on measurements collected by both rain gauges and remote sensing.[68] The potential for endogeneity between the dependent and independent variables is virtually nil given that conflict, in any form, cannot affect the amount of rainfall a country receives in the timeframe measured for their study. The authors, however, may underestimate the risk of omitted variable bias based on the potential impact temperature has on both conflict and precipitation.[69]

2. Conflict Data

Hendrix and Salehyan utilize a dummy variable of 1 as the dependent variable for civil conflict onset when an intrastate conflict for a given country-year exceeds a battle death threshold of 25; all other country-years are represented by 0. The authors collected data for civil conflict from the UCDP/PRIO Armed Conflict Dataset.[70] For social conflict data, Hendrix and Salehyan use a count of the number of social conflict events occurring during a given country-year extracted from the Social Conflict in Africa Database (SCAD).[71] In addition to examining the total number of social conflict events as a whole, the authors present four additional models for the following subcategories: nonviolent events, violent events, government-targeted events, and non-government-targeted events.[72]

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[68] Robert F. Adler, George J. Huffman, and David Bolvin, *Global Precipitation Climatology Project - Daily*, Version 2.1 (Silver Springs, MD: NOAA National Climatic Data Center, 2011).

[69] For temperature and conflict connections see Burke et al., “Warming Increases the Risk of Civil War in Africa.”; John O’Loughlin et al., “Climate Variability and Conflict Risk in East Africa, 1990–2009,” *Proceedings of the National Academy of Sciences of the United States of America*, 109, no. 45 (2012): 18344–18349, http://doi.org/10.1073/pnas.1205130109. For temperature and precipitation see Peter Berg, Christopher Moseley and Jan O. Haerter, “Strong Increase in Convective Precipitation in Response to Higher Temperatures,” *Nature Geoscience* 6 (2013): 181–185, https://doi.org/10.1038/ngeo1731.

[70] Nils Petter Gleditsch et al., “Armed Conflict 1946–2001: A New Dataset,” *Journal of Peace Research* 39, no. 5 (2002): 615–637, https://doi.org/10.1177/0022343302039005007.

[71] Idean Salehyan et al., “Social Conflict in Africa: A New Database,” *International Interactions* 38, no. 4 (2012): 503–511, http://dx.doi.org/10.1080/03050629.2012.697426.

[72] Refer to SCAD codebook and Hendrix and Salehyan, “Climate Change, Rainfall, and Social Conflict in Africa,” for a full description of the various event types.

3. Controls

Consistent with the prevailing conflict literature, Hendrix and Salehyan apply a host of political, economic, and demographic controls to their conflict models. Based on previous studies that find an inverted curvilinear effect between regime type and conflict, the authors use the Polity score (*Polity2*) along with its squared term to control for regime type. For example, Hegre et al. and Muller and Weede find that civil war and social conflict are lower for states that are either highly democratic or highly authoritarian.[73] Development and economic growth are controlled for using real gross domestic product (GDP) per capita (log) and real GDP growth (%) with prior studies linking higher levels of economic prosperity with decreases in the likelihood of both civil war and social conflict.[74] Measures of population (log) and population growth are also included given that larger populations are more likely to experience political protests with rapid growth linked to increased political disorder.[75] Data for the above economic and population indicators are pulled from the Penn World Table version 6.3.[76] Lastly, the authors control for the incidence of civil conflict in their social conflict models due to concerns that civil conflict may suppress participation in and reporting of lower levels of contentious behavior or, conversely, may actually exacerbate large-scale protests.[77]

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[73] Håvard Hegre et al., "Toward a Democratic Civil Peace? Democracy, Political Change, and Civil War, 1816–1992," *American Political Science Review* 95, no. 1 (2001): 33–48, http://www.jstor.org/stable/3117627; Edward Muller and Erich Weede, "Cross-National Variation in Political Violence: A Rational Action Approach," *Journal of Conflict Resolution* 34, no. 4 (1990): 624–651, http://www.jstor.org/stable/174182.

[74] Collier and Hoeffler, "Resource Rents, Governance, and Conflict"; Håvard Hegre and Nicholas Sambanis, "Sensitivity Analysis of the Empirical Literature on Civil War Onset," *Journal of Conflict Resolution* 50, no. 6 (2006): 937–961, https://doi.org/10.1177/0022002706289303; Cullen S. Hendrix, Stephan Haggard, and Beatriz Magaloni, "Grievance and Opportunity: Food Prices, Political Regime, and Protest," Paper presented at the International Studies Association Convention, New York, February, 2009: 15–18, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.600.1898&rep=rep1&type=pdf; Miguel, Satyanath, and Sergenti, "Economic Shocks and Civil Conflict: an Instrumental Variables Approach."

[75] James D. Fearon and David D. Laitin, "Ethnicity, Insurgency, and Civil War," *American Political Science Review* 97, no. 1 (2003): 75–90, https://doi.org/10.1017/S0003055403000534; Henrik Urdal, "People Versus Malthus: Population Pressure, Environmental Degradation, and Armed Conflict Revisited," *Journal of Peace Research* 42, no. 4 (2005): 417–434, https://doi.org/10.1177/0022343305054089.

[76] Alan Heston, Robert Summers, and Bettina Aten, *Penn World Table,* Version 6.3 (Philadelphia, PA: Center for International Comparisons of Production, Income and Prices, University of Pennsylvania, 2009).

[77] Hendrix and Salehyan, "Climate Change, Rainfall, and Social Conflict in Africa," 42.

C. FOOD-RELATED VARIABLES

As part of their mission to defeat world hunger, the Food and Agricultural Organization (FAO) of the United Nations collects and publishes a wide range of food security related data that provide the basis for the following analyses.[78] Although robust in terms of the variety of domains available, incongruences in the categorization of FAO's food metrics can make meaningful calculations across production, trade, and supply statistics rather difficult. Additionally, variations in the caloric density of different foods render direct comparisons of aggregated food metrics, typically measured in tonnes, somewhat meaningless when examined across multiple countries whose diets and agricultural sectors are all unique. Likewise, attempts to compare subcategories (meat, dairy, fruit, etc.) are equally problematic as many of FAO's groupings often fail to align in the exact aggregation of items across the various production, trade, and supply domains.

To overcome these limitations, this thesis focuses on cereal foods as a proxy for overall food supplies. FAO's labeling and aggregation for cereal foods remain largely consistent across all three domains allowing for more direct comparisons across countries. Moreover, cereal based foods are often considered a mainstay of most basic diets and represent a relatively high percentage of the overall food supply across Africa in terms of caloric intake. For the panel years 1989–2008, the median percentage of total food supply (kcal/capita/day) derived from cereals was 50% across 839 country-year data points with a standard deviation of 14.68%.[79] Cereal foods represent over half of the total food supply (kcal/capita/day) for 49% of all country-years observed and at least one-third of the total food supply for 88% of the country-year observations. As such, cereal foods provide a reasonable substitute for overall food when testing food security related issues

[78] Food and Agriculture Organization of the United Nations. *FAOSTAT.* (Rome, Italy: FAO, May 17, 2017). http://www.fao.org/faostat/en/#data.

[79] Percentage calculations based on *Food supply (kcal/capita/day)* element values for *Cereals – Excluding Beer + (Total)* over *Grand Total + (Total)* items aggregated within the Food Supply – Crops Primary Equivalent domain. Data not available for Burundi, Democratic Republic of Congo, Eritrea, Libya, or Somalia.

as potential intermediate linkages between climate change and conflict. Tables 1 and 2 summarize descriptive statistics for cereal foods as a percentage of overall food supply.

Table 1. Country-year cereal supply and overall food supply for 42 African countries, 1989–2000

Variable	*Obs.*	*Mean*	*Median*	*Std. dev.*	*Min.*	*Max.*
Cereal supply (kcal/capita/day)	839	1138.10	1131	419.28	219	2231
Food supply (kcal/capita/day)	839	2321.96	2235	388.86	1508	3490
Cereals as a % of overall food supply	839	48.55%	50%	14.68%	13%	78%

[*] Data not available for Burundi, Democratic Republic of Congo, Eritrea, Libya, and Somalia.

Table 2. Quartile breakdown of cereals as a percentage of overall food supply for 42 African countries, 1989–2008

Variable	*Obs.*	*0-25%*	*25-50%*	*50-75%*	*75-100%*
No. of country-years	839	98	328	395	18

To be clear, the kilocalorie/capita/day data for cereal supply and overall food supply provided by FAO are meant to represent the supply of "processed commodities potentially available for human consumption" and, therefore, one should not construe these figures as representative of the actual caloric intake of foods consumed (in mouth) at the household level.[80] These figures have, however, proven suitable for estimating

80 "Food Balance Sheets and the Food Consumption Survey: A Comparison of Methodologies and Results," Food and Agriculture Organization, accessed November 18, 2017, http://www.fao.org/economic/the-statistics-division-ess/methodology/methodology-systems/food-balance-sheets-and-the-food-consumption-survey-a-comparison-of-methodologies-and-results/en/.

national level surpluses and shortages of food supplies within individual countries—a metric that remains crucial to the resource scarcity and abundance theories.[81]

Data for the annual totals of cereal produced domestically, imported, exported and received as aid are extracted for each country-year (47 countries, 1989-2008).[82] Quantities are measured in tonnes and represent only those crops harvested as dry grains. Fodder crops (forage, silage, and grazing) and crops harvested for industrial purposes are excluded. Models are run utilizing standardized deviations of all four measures, which are derived by calculating the deviation from the long-term (1989-2008) panel mean value for a given country and dividing it by the standard deviation of that country's panel. Utilizing a standardized deviation measure in lieu of actual measured values reduces the cross-sectional differences within the individual variables. Observed values of cereal production, for example, range from 177 tonnes for the Mauritius-2003 country-year to 30,209,000 tonnes for Nigeria-2008. Table 3 provides descriptive statistics for these figures.

Table 3. Standardized deviations for cereal production, cereal imports, cereal exports, and cereal aid for 47 African countries, 1989–2000

Variable	*Obs.*	*Mean*	*Median*	*Std. dev.*	*Min.*	*Max.*
Cereal production	935	0.00	-0.09	1.00	-2.94	3.08
Cereal imports	935	0.00	-0.19	1.00	-2.55	3.20
Cereal exports	915[1]	0.00	-0.30	0.97	-1.69	4.36
Cereal aid[2]	935	0.00	-0.28	1.00	-1.89	4.36

[1] Export data for Mauritania not available.

[2] The FAO database retrieves cereal aid data for 795 country-year observations. A zero values are substituted for the remaining 140 missing values to limit list-wide deletion of country years.

81 Rafael Balanza et al., "Trends in Food Availability Determined by the Food and Agriculture Organization's Food Balance Sheets in Mediterranean Europe in Comparison with other European Areas," *Public Health Nutrition* 10, no. 2 (2007): 168-176, https://doi.org/10.1017/S1368980007246592; Samia Zekaria Gutu, Simon Maxwell, and Rachel Lambert, *Cereal, Pulse and Oilseed Balance Sheet Analysis for Ethiopia, 1979-1989* (Brighton, England: Institute of Development Studies, University of Sussex, 1990); Lluis Serra-Majem, "Food Availability and Consumption at National, Household and Individual Levels: Implications for Food-based Dietary Guidelines Development," *Public Health Nutrition* 4, no. 2 (2001): 673-676, https://doi.org/10.1079/PHN2001152.

82 Export data not available for Mauritania.

To model the effects of precipitation shocks on food supply, a measure of annual cereal supply (measured in tonnes) is constructed using the following equation: *cereal production + cereal imports + cereal aid – cereal exports*.[83] Again, standardized deviations are constructed using the method noted above to reduce cross-sectional differences. Descriptive statistics for cereal supply standardized deviation measures are summarized in Table 4.

Table 4. Standardized deviations for cereal supply and overall food supply for 46 African countries, 1989–2000

Variable	*Obs.*	*Mean*	*Median*	*Std. dev.*	*Min.*	*Max.*
Cereal supply (tonnes)[1]	915	0.00	-0.13	1.00	-2.40	3.09

[1]Cereal supply not calculated for Mauritania due to missing export data.

To estimate a country's dependence on foreign cereal supplies, a foreign-source dependency ratio (FDR) is constructed for each country-year. The FDR is calculated by dividing the sum of a country's foreign cereal sources (imports and aid) by its net availability of cereal (*production + imports + aid – exports*) and then multiplying the quotient by 100.[84] One caveat to this ratio is the assumption that inbound supplies are used for domestic consumption and are not re-exported out of the country. Higher dependence ratios represent greater dependence on outside food sources. A ratio over

[83] Production data is pulled from the *Production – Crops* domain, *Cereals, Total + (Total)* items aggregated, *Production Quantity* group. Import and export data is pulled from the *Trade – Crops and Livestock* domain, *Cereals, + (Total)* items aggregated, *Import/Export Quantity* groups. Cereal aid data is pulled from the *Emergency Response – Food Aid Shipments (WFP)* domain, *Cereals* item. Missing values for production, import, and export data are classified as such leading to the entire country-year being removed from the supply analysis if any one of the three measures are missing. For example, no export data for Mauritania is available and subsequent analysis does not include cereal supply calculations for that country. Missing values for cereal aid, however, are interpreted as zero with no country-years removed from analysis.

[84] FAO calculates an import dependency ratio (IDR) utilizing a similar formula without the inclusion of aid which, for some countries, represents a significant portion of their cereal supply. However, FAO only provides IDR data for the years 2000 and later which fails to overlap with a large portion of the Hendrix and Salehyan study. Additionally, FAO provide their IDR figures as a three-year centered average and, therefore, is not conducive for examining the impact of annual shocks.

50% indicates the majority of a country's cereal supply is obtained via foreign sources for that given year.

For most African countries, the majority of their cereal supplies are derived from domestic production with 642 country-years maintaining a FDR below 50%. This, however, still leaves almost a third of the country-years observed where foreign sources constitute the majority of the country's cereal supply for that year. Additionally, 13 countries maintain a mean FDR greater than 50% for all panel years observed (1989-2008), with five maintaining a mean FDR over 75%. Refer to Tables 5-7 for descriptive statistics.

Table 5. FDRs for 46 African countries, 1989–2008

Variable	*Obs.*	*Mean*	*Median*	*Std. dev.*	*Min.*	*Max.*
FDR[1]	915	37.15%	29%	28.24%	1	124%[*]

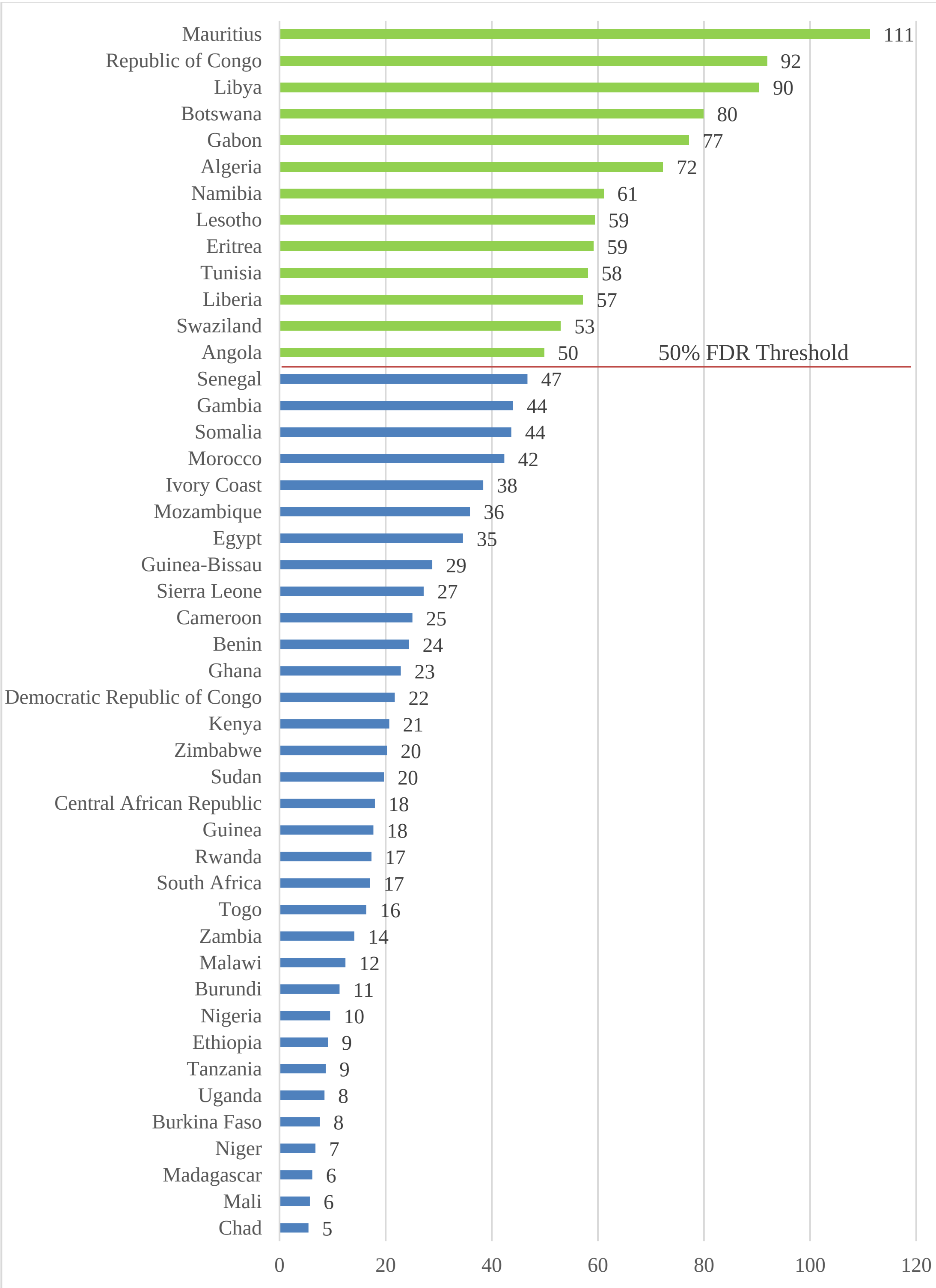
[1] FDR not calculated for Mauritania due to missing export data.

* Mauritius is the only country that displays an FDR over 100 and does so for all panel years. One possible explanation for their outlier status may be a result of their geography as an island nation. Cereal production requires relatively large plots of land and, as such, Mauritius produces almost no cereals. They do, however, import large quantities of cereal foods and, subsequently, export more than they produce. This is likely the of result of reprocessing raw cereals into a secondary exportable good or, perhaps, due to more complex trade mechanics occurring at their port that are beyond the scope of this thesis.

Table 6. Count of country-years broken down into FDR quartile ranges for 46 African countries, 1989–2008

		No. of country years by dependency ratio ranges				
Variable	*Obs.*	*0-25%*	*25-50%*	*50-75%*	*75-100%*	*>100%*
FDR	915	403	239	143	112	18

Table 7. Mean FDR by Country, 1989–2008



D. EFFECTS OF PRECIPITATION ON FOOD SUPPLY

Linear regressions are used to determine the impact of precipitation shocks (independent variable) on a several indicators of food supply (dependent variables) with errors clustered at the country level. Given that most cereal foods maintain a relatively long shelf life, regressions are run using both contemporaneous and lagged independent variables to capture potential carryover of inventories cultivated during the previous year. Although a positive-linear correlation between precipitation and food supply seems the most logical relationship, the squared-terms of both the same-year and lagged independent variables are also included to account for any potential curvilinear affects that may arise due to crop loss, spoilage, and loss of distribution capacity as a result of inundation and flooding during extremely wet years. Odd numbered models correspond to direct linear regressions without applying additional controls for precipitation and cereal production (Model 1), cereal imports (Model 3), cereal exports (Model 5), cereal supply (Model 7), and overall food supply (Model 9). Even numbered models include the political, economic, and demographic controls described above.

Coefficients estimating the effects of precipitation shocks on the various food supply variables are summarized in Table 8 As expected, there is a positive-linear relationship between same-year rainfall deviations and cereal production. The linear effect is strong and statistically significant ($p < 0.01$) when analyzed based on precipitation alone (Model 1) and remains so with the addition of the standard conflict controls (Model 2), although there is a slight reduction in the coefficient estimate from 0.163 to 0.152. Regime type, GDP per capita, and GDP growth also display a positive, statistically significant ($p < 0.01$), linear relationship, with higher levels of democracy, economic output, and economic growth associated with increased cereal yields. There is also evidence ($p < 0.05$) for an inverted curvilinear effect between regime type, however, the slope of this relationship is relatively flat. Overall, these results suggest that wetter than normal years do, in fact, produce better than average yields for cereal foods.

Given that imports are often intended fill the demand gap left by shortfalls in domestic production, one might expect the opposite relationship (a negative-linear correlation) between present rainfall and imports based on the previously discussed link between production and rainfall. Surprisingly, however, present rainfall appears to have little effect on cereal import levels (Models 3 and 4). The previous year's rainfall, on the other hand, does display a strong and statistically significant ($p < 0.01$) negative correlation (Model 3) that strengthens once the host of controls are applied (Model 4), as indicated by a change in the coefficient estimate from -0.105 to -0.124. This finding suggests that many African nations actively adjust their import practices based on production levels, the effects of which, however, are not realized until the following year. A possible explanation for this delay is market and distribution limitations that cause with a temporal lag between the placement of import orders and the actual delivery of goods. For example, countries experiencing lower than normal precipitation and, as a consequent, lower cereal yields will attempt to offset the gap by increasing foreign import orders. However, due to availability, bureaucratic inefficiencies, lack of transportation infrastructure, etc., the bulk of these import orders are not delivered until the following year. A positive coefficient for the squared-term of the lagged rainfall variable, both with (0.062, $p < 0.01$) and without the applied controls (0.070, $p < 0.01$), suggest that this relationship is curvilinear in shape becoming stronger following drier than normal years.

There is little evidence that either present or previous year rainfall has any effect on cereal exports (Models 5 and 6). This lack of correlation is, however, not all that surprising given that most African countries are net food importers and, therefore, often import large quantities of cereal in order to meet domestic demand (Tables 5-7). Several counties have even gone so far as to implement outright bans on the exportation of cereals.[85] As a result, most countries are likely to utilize any increase in production associated with wetter than normal years to help satisfy domestic demand versus attempting to expand their export market.

The relationship between cereal aid deliveries and deviations in precipitation mirrors that of cereal imports (Models 7 and 8). Previous year precipitation and foreign aid display a statistically significant negative correlation (-0.090, $p < 0.01$) that

85 Manitra A. Rakotoarisoa Massimo Iafrate, and Marianna Paschali, *Why has Africa Become a Net Food Importer?* (Rome, Italy: Trade and Markets Division, Food and Agriculture Organization, 2011): 51.

strengthens under the applied controls (-0.106, $p < 0.01$). A potential source for this lagged response might include delays identifying the need for aid, particularly in more remote regions outside the urban centers that then become exacerbated as the request gradually proceeds through multiple bureaucracies that, combined with availability and transportation constraints, push delivery dates into the following year.

Congruent with the previous findings, there is also strong evidence that precipitation shocks have a statistically significant ($p < 0.01$) effect on cereal supplies (Models 9 and 10). Interestingly, with the standard controls applied (Model 10), the larger absolute value of the coefficient estimate reported for lagged linear deviations in rainfall (-0.121) and food supply compared to the coefficient estimate for present deviations in rainfall (0.102) suggest that the cumulative effects of imports and aid on overall cereal supplies surpass those of cereal production. Regime type and GDP growth are also significant at $p < 0.01$ with GDP per capita significant at $p < 0.05$, the effects of which are all positively correlated.

Table 8. Rainfall deviations and food supply deviations, 1990–2008 without controls and 1991–2008 with controls

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*
Variables	*Cereal Production*		*Cereal Imports*		*Cereal Exports*		*Cereal Aid*		*Cereal Supply*	
Rainfall Deviation	0.163***	0.152***	-0.020	-0.025	0.008	-0.011	-0.079*	-0.070	0.114***	0.102***
	(0.049)	(0.046)	(0.036)	(0.041)	(0.034)	(0.036)	(0.045)	(0.046)	(0.038)	(0.035)
Rainfall Deviation²	0.021	0.018	0.032	0.036	-0.023	-0.021	0.015	0.025	0.029	0.030
	(0.030)	(0.028)	(0.027)	(0.026)	(0.017)	(0.017)	(0.027)	(0.027)	(0.030)	(0.026)
Rainfall Deviation, lagged	-0.022	-0.026	-0.105***	-0.124***	0.004	0.001	-0.090***	-0.106***	-0.101**	-0.121***
	(0.040)	(0.038)	(0.035)	(0.036)	(0.033)	(0.032)	(0.032)	(0.037)	(0.040)	(0.039)
Rainfall Deviation², lagged	0.041	-0.004	0.062***	0.070***	0.010	0.001	0.004	0.029	0.064**	0.048*
	(0.030)	(0.026)	(0.022)	(0.024)	(0.022)	(0.026)	(0.044)	(0.025)	(0.025)	(0.026)
Polity2		0.022***		0.023***		0.003		-0.010		0.028***
		(0.008)		(0.008)		(0.007)		(0.007)		(0.008)
Polity2²		-0.005**		-0.003		-0.001		0.001		-0.004**
		(0.002)		(0.002)		(0.002)		(0.002)		(0.002)
log Population		0.035		0.034*		0.004		-0.009		0.038
		(0.025)		(0.020)		(0.016)		(0.015)		(0.026)
Population growth		0.461		-3.384		-0.996		0.768		-1.433
		(1.526)		(3.035)		(1.353)		(1.791)		(1.600)
log Real GDP per capita		0.105***		0.041		0.067**		-0.045*		0.085**
		(0.035)		(0.036)		(0.027)		(0.027)		(0.040)
Real GDP growth, %		0.014***		0.008*		0.006		-0.006		0.015***
		(0.004)		(0.004)		(0.004)		(0.004)		(0.004)
Constant	-0.052	-1.033***	-0.038	-0.518	0.026	-0.466*	-0.025	0.322	-0.050	-0.931**
	(0.054)	(0.377)	(0.045)	(0.381)	(0.031)	(0.268)	(0.044)	(0.290)	(0.050)	(0.418)
Observations	889	828	889	828	870	810	889	828	870	810
Countries	47	47	47	47	46	46	47	47	46	46

Standard errors in parentheses; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Combined, this evidence supports Hypothesis 1 that deviations from precipitation patterns do, in fact, affect cereal supplies. Additionally, these findings indicate that, based on the larger coefficient estimate for previous versus present rainfall deviations, fluctuations in rainfall occurring the previous year actually have a greater impact on cereal supplies—a phenomena not previously discussed in the bulk of climate change-conflict research. This lag effect has the potential to exacerbate food security conditions both in the positive and negative direction. Higher than normal harvests, as the result of wetter than normal condition, will lead to lower levels of import orders—the impact of which are not felt until the following year. If a wetter than normal year is immediately followed by a drought year, both production and import levels could end up significantly lower leading to extreme food shortages. Conversely, a drought year followed by a wetter than normal year has the potential to create larges surpluses that may contribute to a number of conflict inducing behaviors associated with the abundance theory of conflict.

E. EFFECT OF FOREIGN FOOD DEPENDENCE ON PRECIPITATION-INDUCED CONFLICT

To determine whether a country's dependence on foreign-sourced cereals alters the broader linkage between climate change-induced fluctuations in precipitation and the incidence of conflict, a reanalysis of Hendrix and Salehyan's conflict models is conducted with countries separated into two groups—those that rely heavily on foreign cereal sources (FDR > 50%) and those who produce the majority of their cereal foods domestically (FDR < 50%). Because Hendrix and Salehyan's original models yield significant findings for contemporaneous rainfall but not the previous year's rainfall, lagged FDRs are utilized to limit potential multicollinearity given that rainfall affects both conflict and FDR (via its effect on cereal production).

Hendrix and Salehyan's original model for measuring the impact of precipitation shocks on the incidence of civil conflict uses logistic regression with errors clustered at the country level and a cubic polynomial approach for interpreting time dependence of years since the last conflict. Controls are applied using their lagged measures. The model is run on a sample of 47 countries for the years 1991-2008 with a total of 828 country-year observations. Table 9 reports the replicated results of Hendrix and Salehyan's original civil conflict model (Model 11). The authors find a statistically significant ($p < 0.01$) positive, linear relationship between present rainfall deviations and the onset of civil war and insurgency. Population growth is the only standard control within their model to show an impact ($p < 0.05$) on civil conflict with higher rates of growth increasing the probability of conflict. Overall, their findings suggest that civil war is more likely to occur during wetter than normal conditions.

To facilitate side-by-side comparisons, Table 9 also includes the reanalysis results of the civil conflict models separated by FDR. Model 12 is run for countries with a FDR less than 50% (n=562), while Model 13 includes those countries with a FDR greater than 50% (n=266). For countries that produce the majority of their cereal supplies domestically, the present effect of rainfall shocks on civil conflict strengthens when compared to the original model showing an increase in the coefficient estimate from 0.405 to 0.478, statistically significant at $p < 0.01$. The linear effect remains positive with wetter than normal years increasing the probability of civil conflict. For countries that rely heavily on foreign sources to maintain their cereal supplies, the statistical significance between precipitation shocks and civil conflict completely disappears.

These findings support Hypothesis 2, which suggests that dependence on foreign cereal sources dampen the effects of precipitation shocks on the incidence of civil conflict. In fact, for countries that import the majority of their annual cereal supplies, the connection between rainfall and civil conflict all but evaporates. Furthermore, the strengthening of the positive relationship between rainfall and civil conflict for countries with relatively low FDRs further supports Hypothesis 2. Additionally, this strong positive relationship gives credence to the abundance theory of conflict, which argues that bountiful harvests can provide the necessary resources to recruit, feed, and fund insurgencies while also providing potential grievances over the distribution of wealth derived from increased yields.

Table 9. Rainfall deviations and civil conflict separated by FDR, 1991–2008

	(11) *Original Model*	*(12)* *Lagged FDR < 50%*	*(13)* *Lagged FDR > 50%*
Variables	***Civil conflict onset***		
Lagged dependent variable	-2.494***	-2.927***	-3.227***
	(0.689)	(0.715)	(1.036)
Rainfall deviation	0.405***	0.478***	0.344
	(0.156)	(0.172)	(0.216)
Rainfall deviation^2	-0.077	-0.194	0.010
	(0.069)	(0.144)	(0.076)
Rainfall deviation, lagged	-0.101	-0.255	0.210
	(0.151)	(0.193)	(0.181)
Rainfall deviation^2, lagged	-0.043	0.021	-0.356
	(0.088)	(0.073)	(0.357)
Polity2, lagged	0.013	0.014	-0.010
	(0.031)	(0.042)	(0.073)
Polity2^2, lagged	-0.010	0.002	-0.029***
	(0.009)	(0.014)	(0.008)
log Population, lagged	0.079	-0.066	0.584**
	(0.110)	(0.174)	(0.242)
Population growth, lagged	0.014**	0.006	0.018***
	(0.006)	(0.021)	(0.006)
log Real GDP per capita, lagged	-0.191	-0.647	0.031
	(0.288)	(0.424)	(0.327)
Real GDP growth, %, lagged	-0.004	-0.032**	-0.756**
	(0.010)	(0.018)	(0.013)
Constant	-0.425	4.235	-4.717
	(2.157)	(2.862)	(2.251)
Controls for temporal dependence	Yes	Yes	Yes
Observations	828	562	266
Countries	47	41	25

Robust standard errors, clustered on countries in parentheses.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Shifting to social conflict, Hendrix and Salehyan model the effects of precipitation shocks on several categories of social conflict using negative binomial regression estimated on the pooled time time-series cross-sectional.[86] Standard errors are clustered on countries and controls are applied using their present measures. Year dummies are also included in their models to control for broader conditions that may affect social conflict levels across all countries in the same given year. Their social conflict models are run on a sample that includes 46 countries for the years 1991-2007 with 765 country-year observations.[87]

Replication results for their original models are included in the left-hand column models of Tables 10-14.[88] The authors find a curvilinear U-shaped relationship between both positive and negative deviations for contemporaneous rainfall, based on the squared term, and social conflict for total social conflict events (Table 10, Model 14) and all four of the social conflict subcategories: nonviolent (Table 11, Model 17), violent (Table 12, Model 20), government-targeted (Table 13, Model 23), and non-government-targeted events (Table 14, Model 26). These findings are statistically significant at $p < 0.01$ for all but non-government-targeted events ($p < 0.05$). When comparing the marginal effects of present rainfall deviation, the authors also find that violent events are more likely to occur during wetter than normal years.

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[86] The authors also run their social conflict models using conditional country fixed effects as a robustness check, however, this thesis is primarily concerned with comparing the results of the time-series cross-sectional models with the additional FDR controls. The results of Hendrix and Salehyan's conditional country fixed effects largely confirm their time-series cross-sectional findings. For a complete summary of their results please refer to the original study.

[87] Hendrix and Salehyan drop Somalia due to its lack of functioning government and conflict attributed to foreign intervention.

[88] When replicating Hendrix and Salehyan's original social conflict models, all coefficient estimates matched those published in their paper except for time trend and the constant. Estimates reported in the attached models (odd numbered models located in Tables 9-13) represent data extracted during the replication attempts.

Table 10. Cereal supply and total social conflict events separated by FDR, 1991–2007

	(14) Original Model	*(15) Lagged FDR < 50%*	*(16) Lagged FDR > 50%*
Variables		***Total events***	
Lagged dependent variable	0.049***	0.042***	0.065***
	(0.009)	(0.008)	(0.012)
Rainfall deviation	-0.015	0.025	-0.097
	(0.032)	(0.037)	(0.063)
Rainfall deviation²	0.072***	0.069***	0.108***
	(0.018)	(0.019)	(0.041)
Rainfall deviation, lagged	-0.018	0.000	-0.076
	(0.038)	(0.052)	(0.069)
Rainfall deviation², lagged	0.015	-0.004	0.067
	(0.028)	(0.036)	(0.048)
Polity2	-0.015	-0.014	-0.016
	(0.012)	(0.010)	(0.017)
Polity2²	-0.000	0.001	-0.005
	(0.003)	(0.003)	(0.005)
log Population	0.331***	0.309***	0.332***
	(0.062)	(0.065)	(0.110)
Population growth, %	-4.134*	-7.981	-1.519
	(2.112)	(6.786)	(1.464)
log GDP per capita	-0.107	0.009	-0.153
	(0.074)	(0.102)	(0.110)
Real GDP growth, %	-0.012**	-0.022***	-0.001
	(0.005)	(0.005)	(0.006)
Civil conflict incidence	0.055	0.056	-0.004
	(0.098)	(0.109)	(0.193)
Time trend	-0.229	-0.289	-0.083
	(0.178)	(0.182)	(0.398)
Constant	2.905	3.498	0.545
	(3.314)	(3.354)	(7.164)
Observations	765	520	245
Countries	46	40	23

Robust standard errors, clustered on countries in parentheses.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 11. Cereal supply and nonviolent social conflict events separated by FDR, 1991–2007

	(17) Original Model	(18) Lagged FDR < 50%	(19) Lagged FDR > 50%
Variables	***Nonviolent events***		
Lagged dependent variable	0.093***	0.079***	0.124***
	(0.015)	(0.012)	(0.038)
Rainfall deviation	-0.042	-0.007	-0.103*
	(0.039)	(0.045)	(0.056)
Rainfall deviation²	0.068***	0.068***	0.097**
	(0.021)	(0.023)	(0.047)
Rainfall deviation, lagged	-0.027	0.004	-0.116**
	(0.035)	(0.046)	(0.059)
Rainfall deviation², lagged	0.002	-0.034	0.094*
	(0.026)	(0.031)	(0.051)
Polity2	-0.017	-0.015	-0.018
	(0.012)	(0.010)	(0.017)
Polity2²	0.003	0.003	0.001
	(0.003)	(0.003)	(0.006)
log Population	0.290***	0.254***	0.284**
	(0.053)	(0.058)	(0.115)
Population growth, %	-3.894	-6.607	-0.381
	(2.442)	(6.383)	(1.756)
log GDP per capita	-0.090	0.050	-0.134
	(0.079)	(0.100)	(0.117)
Real GDP growth, %	-0.009	-0.019***	-0.005
	(0.006)	(0.007)	(0.005)
Civil conflict incidence	0.123	0.136	-0.069
	(0.095)	(0.095)	(0.233)
Time trend	-0.349	-0.305	-0.491
	(0.225)	(0.236)	(0.455)
Constant	4.626	3.403	6.910
	(4.209)	(4.564)	(8.518)
Observations	765	520	245
Countries	46	40	23

Robust standard errors, clustered on countries in parentheses.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 12. Cereal supply and violent social conflict events separated by FDR, 1991–2007

	(20) *Original Model*	*(21)* *Lagged FDR < 50%*	*(22)* *Lagged FDR > 50%*
Variables		***Violent events***	
Lagged dependent variable	0.081***	0.072***	0.115***
	(0.015)	(0.015)	(0.015)
Rainfall deviation	0.032	0.077*	-0.055
	(0.035)	(0.043)	(0.118)
Rainfall deviation²	0.084***	0.080***	0.115**
	(0.026)	(0.027)	(0.060)
Rainfall deviation, lagged	0.014	0.022	-0.016
	(0.056)	(0.072)	(0.111)
Rainfall deviation², lagged	0.033	0.023	0.081
	(0.040)	(0.049)	(0.073)
Polity2	-0.003	0.000	-0.005
	(0.014)	(0.014)	(0.024)
Polity2²	-0.005	-0.003	-0.013**
	(0.003)	(0.003)	(0.005)
log Population	0.439***	0.452***	0.460***
	(0.075)	(0.084)	(0.176)
Population growth, %	-4.747**	-9.412	-4.146***
	(2.213)	(7.781)	(1.557)
log GDP per capita	-0.116	-0.001	-0.243**
	(0.079)	(0.110)	(0.121)
Real GDP growth, %	-0.017**	-0.028***	-0.008
	(0.007)	(0.009)	(0.007)
Civil conflict incidence	-0.046	-0.012	-0.339
	(0.152)	(0.172)	(0.353)
Time trend	-0.072	-0.214	0.276
	(0.206)	(0.217)	(0.468)
Constant	-1.513	0.105	-6.476
	(3.620)	(3.742)	(8.252)
Observations	765	520	245
Countries	46	40	23

Robust standard errors, clustered on countries in parentheses.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 13. Cereal supply and government-targeted social conflict events separated by FDR, 1991–2007

	(23) Original Model	*(24) Lagged FDR < 50%*	*(25) Lagged FDR > 50%*
Variables	***Government-targeted events***		
Lagged dependent variable	0.091***	0.084***	0.117**
	(0.014)	(0.011)	(0.058)
Rainfall deviation	-0.012	0.057	-0.162**
	(0.043)	(0.048)	(0.081)
Rainfall deviation²	0.074***	0.055**	0.152***
	(0.025)	(0.024)	(0.043)
Rainfall deviation, lagged	-0.058	-0.036	-0.134*
	(0.042)	(0.052)	(0.070)
Rainfall deviation², lagged	-0.003	-0.031	0.071
	(0.029)	(0.037)	(0.061)
Polity2	-0.016	-0.014	-0.017
	(0.013)	(0.009)	(0.021)
Polity2²	0.001	0.002	-0.004
	(0.003)	(0.003)	(0.005)
log Population	0.276***	0.209***	0.310**
	(0.058)	(0.055)	(0.153)
Population growth, %	-4.733	-5.882	-1.329
	(2.918)	(6.029)	(2.874)
log GDP per capita	-0.105	0.029	-0.164**
	(0.087)	(0.093)	(0.117)
Real GDP growth, %	-0.013**	-0.026***	0.005
	(0.006)	(0.006)	(0.005)
Civil conflict incidence	-0.018	-0.021	-0.118
	(0.107)	(0.111)	(0.256)
Time trend	-0.284	-0.307	-0.218
	(0.238)	(0.239)	(0.543)
Constant	3.851	4.000	2.696
	(4.231)	(4.366)	(9.478)
Observations	765	520	245
Countries	46	40	23

Robust standard errors, clustered on countries in parentheses.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 14. Cereal supply and non-government-targeted social conflict events separated by FDR, 1991–2007

	(26) Original Model	*(27) Lagged FDR < 50%*	*(28) Lagged FDR > 50%*
Variables	***Non-government-targeted events***		
Lagged dependent variable	0.080***	0.060***	0.138***
	(0.019)	(0.015)	(0.043)
Rainfall deviation	-0.023	-0.022	0.066
	(0.037)	(0.044)	(0.079)
Rainfall deviation²	0.072**	0.090***	-0.019
	(0.031)	(0.029)	(0.060)
Rainfall deviation, lagged	0.044	0.044	0.087
	(0.049)	(0.066)	(0.082)
Rainfall deviation², lagged	0.039	0.034	0.006
	(0.034)	(0.035)	(0.089)
Polity2	-0.002	0.008	-0.011
	(0.015)	(0.015)	(0.030)
Polity2²	-0.003	-0.003	-0.006
	(0.003)	(0.003)	(0.005)
log Population	0.494***	0.586***	0.389***
	(0.092)	(0.083)	(0.140)
Population growth, %	-4.563**	-11.364	-2.665
	(2.096)	(7.619)	(1.938)
log GDP per capita	-0.058	0.104	-0.143
	(0.113)	(0.125)	(0.183)
Real GDP growth, %	-0.013*	-0.020**	0.011
	(0.008)	(0.009)	(0.009)
Civil conflict incidence	0.136	0.222	-0.041
	(0.153)	(0.180)	(0.197)
Time trend	-0.201	-0.263	0.230
	(0.139)	(0.164)	(0.274)
Constant	-0.305	-1.048	-6.333
	(2.850)	(3.399)	(4.862)
Observations	765	520	245
Countries	46	40	23

Robust standard errors, clustered on countries in parentheses.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Reanalysis results controlling for FDR are also summarized in Tables 10-14 with models isolating countries with a FDR less than 50% located in the center column and models with counties exhibiting a FDR greater than 50% displayed in the right-hand column models. In contrast to the dampening effect of high FDRs on civil conflict, a higher FDR appears to have the opposite effect on most social conflict events. The coefficient estimates for total events (Table 10, Model 16), nonviolent (Table 11, Model 19), violent events (Table 12, Model 22), and government-targeted events (Table 13, Model 25) actually increase for countries with a FDR greater than 50%. Conversely, countries that produce the majority of their cereal foods (FDR <50%) experience either a reduction in their coefficient estimates or simply no change across the same social conflict event types (Tables 10-13, center column models). This divergent effect may actually indicate a stepped approach to conflict intensity. Countries with larger agriculture sectors (lower FDRs) are more likely to experience larger swings in food supplies as a result of fluctuations in precipitations than majority importers (higher FDRs). These resource fluctuations have the potential to reach levels extreme enough, as indicated in Table 9 results, to alter the cost-benefit analysis of individual actors and funding streams necessary to mobilize and sustain civil conflict, civil conflict being more intensive and riskier than lower forms of social conflict. Conversely, the resource instabilities occurring in high FDR countries are likely to be much less and, perhaps, only reach levels significant enough to initiate lower levels of social conflict, levels that low FDR countries have already surpassed.

The only category in which higher FDRs create a dampening effect is non-government-targeted events (Table 14, Model 28). In these cases, the correlation between precipitation shocks and non-government-targeted events initially present in Hendrix and Salehyan's original model effectively disappears. Additionally, the coefficient estimate for countries producing the majority of their cereal supplies strengthens, as it did in the case of civil conflict events, when compared to the original model, as well as increasing in statistical significance (Table 14, Model 27). A potential explanation for this finding may lie in the underlying resource driving the conflict. Again, fluctuations in cereal supplies are less likely to occur in high FDR countries whereas the fluctuation in water supplies could be much more extreme for these countries following variations in precipitation—water sensitivity perhaps being the causal reason for a country's higher FDR. Water rights and distribution infrastructures are typically government controlled functions which may cause them to take the brunt of public malcontent that surfaces during anomalously wet and dry years in high FDR countries. The contrasting effect of which is lower instances of non-government-targeted conflict in high FDR countries.

Performance of the control variables in the original models were inconsistent and remain so under reanalysis. Population is the most stable with statistically significant (minimum significance of $p < 0.05$) positive, linear effects appearing across all original and FDR isolated models. Population growth and real GDP growth each display varying degrees of a negative, linear effect within several categories of social conflict; however, both variables are somewhat erratic when compared across all models.

Overall, these results provide mixed support for Hypothesis 2. Models 12 and 13 provide evidence that the degree to which a country depends on foreign sources for food supplies significantly alters the effect that large deviations in precipitation have on influencing the onset of civil war and insurgency. As suggested in Hypothesis 2, countries who import the majority of their cereal supplies are insulated from the positive, linear relationship between precipitation shocks and conflict while countries who cultivate the majority of their cereal domestically are more susceptible to this effect. Likewise, Models 27 and 28 provide similar evidence that higher FDRs dampen the effects of precipitation shocks on non-government-targeted social conflict events.

For violent, nonviolent, and government-targeted events, the assumption that a country's FDR plays a role in how deviations from normal rainfall patterns impact social conflict continues to hold true. However, contrary to Hypothesis 2, higher FDRs amplify the observed connection between precipitation shocks and the outbreak of these three forms of social conflict. The fact that civil conflict and government-targeted social conflict fail to align within the results is of particular interest given that the government represents one side of the conflict in both cases. Again, potential explanations for the contrasting effects may lie in the progressive nature of conflict from lower levels of social conflict to full-blown civil war. Arguably, nonviolent, non-government-targeted actions represent the least costly form of conflict, both in terms of risk and required resources, with civil conflict residing on the opposite end of that continuum. Since higher FDRs are likely to limit the intensity of cereal supply fluctuations associated with deviations in rainfall, the effects of anomalous rainfall may only begin to materialize in high FDR countries at lower levels of conflict—indicative in the absence of correlation for civil conflict for these countries. Low FDR countries, on the other hand, experience fluctuations in cereal supplies large enough to impact the incidence of more intensive conflict actions up through civil war

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V. DISCUSSION

The main objective of this thesis was to determine whether a country's reliance on foreign sourced food supplies alters the impact of climate change-induced conflict within African nations. To test this hypothesis, this thesis reanalyzed a study by Hendrix and Salehyan examining the impact of precipitation on various levels of conflict by separating countries as majority producers and majority importers of cereal foods. The results of these isolated regressions indicate that a country's dependence on foreign food sources does, in fact, matter.

Three major conclusions can be drawn from these results. First, the ability of African countries to respond efficiently to fluctuations in food production falls short as evidenced by the lagged response of cereal supplies, imports in particular, to significant deviations in precipitation. Second, countries that secure the majority of their cereal supplies from foreign sources, through either importation or emergency aid, are insulated from the impacts of rainfall deviations on civil conflict. Third, the effect of fluctuations in precipitation on most lower levels of social conflict is greater in countries with relatively high FDRs when compared to countries that produce the majority of their food.

When discussing national security, resource independence is often touted as a primary objective. This thesis, however, suggests that, in the case of food, a more diversified approach to maintaining food security might actually reduce a country's risk of climate change-induced conflict. As the variability of precipitation patterns increase, the risk of falling victim to large swings in food supplies become greater for countries that rely more heavily on domestic agricultural production. Additionally, for countries whose overall economies are largely agrarian in nature, as is the case across much of Africa, extreme fluctuations in annual harvests have the potential to induce corresponding fluctuations in incomes which, in turn, increases the probability of conflict even further.

For policy makers, investments focused on improving water management infrastructure as a means to stabilize water supplies have the potential to reduce the impacts of anomalously wet and dry conditions on the overall incidence of conflict.

Additionally, this thesis demonstrates a need for countries to develop more responsive commodity markets to manage and forecast food supplies following large swings in domestic production. The current lag times exhibited between production losses following drought conditions and the receipt of foreign imports and emergency aid may prove too lengthy to prevent immediate food shortages. Likewise, it appears as though many countries fail to take advantage of bumper crops as an opportunity to stockpile cereals to maintain future levels of food security and, instead, simply cut back on imports—perhaps to reduce government spending.

With regards to future climate change-conflict research, this study highlights the need to investigate how social, political, economic, and environmental factors may influence the impacts of climate change on the incidence of conflict at each intermediate linkage along the causal chain. On the surface, the results of this thesis would seem to suggest that if a country's climate becomes more arid, thereby reducing its overall agricultural capacity, it will become less prone to civil war given that its FDR will likely go up. That, however, is a rather dangerous and misguided assumption to make. It is inconceivable to assume that variations in climatic conditions will impact all nations equally.

Researchers must resist a broad-brush approach to applying potential causal connections evenly across all countries and instead dig deeper to uncover the various intermediate mechanisms and underlying conditions that propel one society towards conflict while leaving another society relatively unscathed. Zimbabwe and Botswana, for example, exist in relative close geographic proximity and yet the individual strategies they employ to secure their food, whether by choice or by necessity, exist on opposite ends of the spectrum with Zimbabwe importing 20% of its cereal supplies while Botswana imports upwards of 80%. Exhibiting a relatively high FDR is not necessarily indicative of a country's *need* to import food based on environmental conditions. Instead, it may simply represent a government's *willingness* to import food, a trait typically beholden to more democratic nations and their increased attentiveness to the needs of their citizens.[89] As Nobel Laureate Amartya Sen once noted, “there has never been a famine in a functioning multiparty democracy.”[90] In other cases, a high FDR could merely indicate a country’s *ability* to import food due to economic prosperity or abundant oil reserves. A country that relies heavily on foreign food sources may appear somewhat insulated from certain precipitation related effects of climate change; however, the underlying conditions that influence a country’s FDR vary and, in turn, may leave it vulnerable to an alternate set of risks.

Ultimately, the end goal is to identify the specific risk factors at the country-level that increases a particular nation’s vulnerability to conflict. Climate change itself, rising global temperatures and warming oceans, will not necessarily cause more conflict and most certainly will not impact all nations equally. The consequences however, of a changing climate, such as shifts in growing seasons and weather related natural disasters, are predicted to increase in both frequency and intensity. These disruptive events, in turn, have the potential to expose or exacerbate underlying social, political, and economic conditions that are conducive to conflict. Risk analysis and resilience building require a holistic approach. Although we continue to improve our ability to predict where the broader manifestations of climate change are likely to occur, we must also strive to expand our ability to measure and increase the individual resilience capacity of countries that find themselves directly in climate change’s crosshairs. Mitigation strategies concentrated at the national-level to better address a country’s individual resilience gaps and simultaneous efforts to combat global climate change have the potential to promote a more verdant and peaceful society.

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[89] Amartya Sen, *Development as Freedom* (New York, NY: Anchor Books, a division of Random House, Inc., 1999), 178-184.

[90] Ibid., 178.

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