EPICENTERS OF CLIMATE AND SECURITY:

THE NEW GEOSTRATEGIC LANDSCAPE OF THE ANTHROPOCENE

Edited by:

Caitlin E. Werrell and Francesco Femia

THE CENTER FOR CLIMATE AND SECURITY

EPICENTERS OF CLIMATE AND SECURITY: THE NEW GEOSTRATEGIC LANDSCAPE OF THE ANTHROPOCENE

June 2017

Edited by:
Caitlin E. Werrell and Francesco Femia

THE CENTER FOR CLIMATE AND SECURITY

Sponsored by:

skoll global threats fund

In partnership with:

Carnegie Mellon University
Civil and Environmental Engineering

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT
UNIVERSITY OF OXFORD

Energy Science Technology & Policy
Carnegie Mellon University
College of Engineering

ASP
American Security Project

Planetary Security INITIATIVE

Contents

Note From The Editors

Caitlin Werrell and Francesco Femia

"Epicenters of Climate and Security: The New Geostrategic Landscape of the Anthropocene" is a multi-author, edited volume exploring a range of "epicenters" of climate and security and how they shape the geostrategic map of the 21st century. These epicenters are defined as "categories of systemic risk" driven by a changing climate interacting with other socio-political-economic dynamics.

A systemic risk is a risk to a component or components of a system that, due to the critical nature of the components, can significantly disrupt (and sometimes collapse) the whole system that depends on it. In this report, an "epicenter" is defined as a category of systemic risk, or simply a collection of systemic risks with similar characteristics – a kind of "super-systemic risk." For example, the Strait of Malacca is a major maritime trade route connecting the Indian and Pacific Oceans that is critical for global trade and security. Risks to freedom of navigation through the Strait of Malacca, or broader risks to the stability of the Strait, can therefore be described as a systemic risk to global trade and global security. However, there is more than one critical maritime trade route in the world. The Strait of Hormuz, the Panama Canal, the Arctic Northwest Passage are just a few of these critical nodes in the global trade system. Many of these straits will face disruptions as a result of a changing climate. Together, these straits present a category of systemic risks to global trade and security, and are therefore considered an "epicenter" of climate and security.[1] This volume explores many such epicenters.

These epicenters are, in many ways, without precedent and unique to the "Anthropocene" era - the period of Earth's history we are currently in, according to Simon Lewis and

Mark Maslin.[2] The Anthropocene is characterized by humans having considerably (and possibly irreversibly) altered the global ecosystem, including the atmosphere. The risks described in each of the epicenter chapters are risks that could exist, in one form or another, during a time of climate stability. However, rapid climate change exacerbates these risks significantly.

These epicenters encompass a range of critical geographies that together make up central pillars of global security. Their vulnerability to climate change presents a significant risk to that security. The epicenters of climate and security explored in this report have characteristics that meet the following three criteria:

1. Critical for global security (e.g. a localized disruption to the epicenter could scale-up to higher order security scenarios and to the regional and international scale);

2. Vulnerable to a rapidly-changing climate (e.g. increased intensity and frequency of extreme weather events, sea level rise);

3. Categories of risk present in multiple locations around the world, rather than being specific to one geographic location (e.g. megacities, small island nations, water-weaponization).

Each of these epicenters, individually – indeed, each of the systemic risks contained within each epicenter - should be cause for concern among policy-makers and planners worldwide. Collectively, however, the vulnerability of these epicenters presents a potentially dramatic threat to global security with considerable disruption to the geostrategic landscape. In that context, each chapter in this volume presents a particular "epicenter," while the whole volume presents a picture of a potentially unprecedented threat to global security. Hence, the nature of these risks mean that the tools required to anticipate and manage them will have to evolve to find the signals in the noise.

Notes

1 See "Dire Straits: Strategically-significant International Waterways in a Warming World," by Adam H. Goldstein and Constantine Samaras in this volume for more on straits as epicenters of climate and security.

2 Lewis, S, and Maslin, M, "Defining the Anthropocene," *Nature*, Vol 519, pp. 171-180, March 12, 2015

Introduction

Shiloh Fetzek and Bessma Mourad

Multilateral political treaties. Just-in-time supply chains. Internet server infrastructure. Each of these illustrates the complex web of interdependence and reciprocity in our globalized society. The threats and challenges that confront it are often just as complex, with climate change being a particularly wicked problem, as uncertainties are many, impacts are diffuse, and the risks are constantly evolving.

The chapters in this volume explore the nature of epicenters of risk and highlight examples of how climate impacts can intersect, amplify and ripple across countries or regions in unexpected ways. Topics examine the central themes and drivers of the climate and security field – agriculture, energy, water, migration – but also look beyond the climate-conflict nexus, to connect the dots across sectors and examine unanticipated or under-explored climate impacts on the broader geostrategic landscape.

Christine Parthemore explores how the dynamics of nuclear security in the Anthropocene present growing risks and complexities as the world considers how to use nuclear power as a low-carbon energy source. Growth in nuclear capabilities may happen in novel ways, in new regions, and may give rise to complex geopolitical challenges, as with, for example, China's plans to build floating nuclear reactors in disputed areas of the South China Sea. With fast-breeder reactors planned in countries such as India as a measure to address climate change, weak governance and the risk of theft of nuclear materials by non-state armed groups could create new and challenging risks.

Climate impacts on a range of economic sectors could also scale up into higher-order security challenges, threatening both food security and livelihoods. Much attention has

rightly been focused on the effects of climate change on staple and subsistence crops, but fisheries and cash crops are also important areas to examine. Michael Thomas examines the risks fisheries face from the Arctic, to the South China Sea, and to the Great Lakes region in Africa. With fishing rights already a source of competition that has occasionally sparked confrontation between fishing fleets and nations, these dynamics will worsen as climate change exacerbates resource depletion in combination with overexploitation.

Climate change will also dramatically shift the areas suitable for growing some cash crops, including coffee, in the coming decades. Shiloh Fetzek shows that the countries whose economies are most dependent on coffee exports also face underlying security risks. Many of these countries, including the growers and laborers who produce their coffee crops, face potentially devastating economic consequences from climate change that could exacerbate transnational security issues.

The transnational ripple effects of climate impacts on water are also substantial and varied. Troy Sternberg, as well as Marcus King and Julia Burnell explore two particular angles - the risks that are common to geographies whose water source is snow melt from mountain ranges, and how water is being weaponized by non-state armed groups such as ISIS and Boko Haram. The dynamics of water weaponization currently observed in some parts of the world – notably the Middle East and North Africa - could come into play in other regions, potentially with broader geopolitical impacts.

Changing oceans – from sea level rise to a transforming Arctic, as explored by Katarzyna Zysk and David Titley – will also transmit risks across geographies. Small island states and coastal megacities face threats from rising seas, contributing to migration pressures and governance challenges, as outlined by Andrew Holland and Esther Babson, as well as Janani Vivekenanda and Neil Bhatiya. Many coastal megacities are under-equipped for the challenges they face from climate change, and what happens in cities can often destabilize neighboring regions and strategically significant waterways - issues addressed by Adam Goldstein and Constantine Samaras.

While each of these issues may begin as a localized event, they are often interconnected. Migration and health are two examples. Robert McLeman looks at potential increases in forced migration globally, and Kaleem Hawa illustrates the complex intersection of climate change, health and international security.

Any one of these risks - never mind combinations of them - may contribute to the erosion of the social contract between citizens and their governments in a number of states across the world, which can have a significant impact on world order. Francesco Femia and Caitlin Werrell explore this dynamic.

The approaches that decision-makers use to manage risk must evolve with the changing nature of risk in a climate-changed world. The last section of this report explore the tools and practices necessary for addressing these epicenters of climate and security. The chapters emphasize preventive modes of governance that will require new and more versatile tools for anticipating, managing, mitigating and eliminating these risks.

Sinead O'Sullivan explores how Earth observation technologies such as satellites and drones can provide data to enhance situational awareness around climate and environmental changes, and support data-driven decision-making to manage epicenters of risk in the Anthropocene. Detailed mapping of the most climate-vulnerable and unstable areas can also help to identify which localities are the highest priority for interventions and shape decision-making and early warning systems to limit the potential for localized disruptions to scale up into regional security issues, as outlined by Joshua Busby.

Finally, foresight tools including vulnerability assessments and scenario building can help to surface potential interactions and combinations of events that can inform risk management decision-making, while advances in the digital age may provide new ways of monitoring and identifying patterns of emerging systemic risk, as outlined by Bessma Mourad and Amy Luers as well as Chad Briggs.

While such complex problems are by their nature difficult to solve, it is necessary to understand, manage, and develop effective approaches to address them. This volume demonstrates the kind of cross-sectorial thinking needed to anticipate and mitigate climate-related systemic risk and the interconnected categories of risk that are increasingly likely in the new geological and geopolitical age.

CLIMATE AND SECURITY EPICENTERS

Climate Change, the Erosion of State Sovereignty, and World Order[1]

Francesco Femia and Caitlin E. Werrell[2]

The formation and spread of the nation-state has occurred during a relatively stable climatic period—an 11,000-year-plus epoch referred to by geologists as the Holocene.[3] The Holocene, thought to be the longest warm and "stable" climatic period of the last 400,000 years, may have played a significant role in facilitating the development of human civilization.[4] The epoch encompasses the advent of agriculture, the rise and fall of empires and monarchs, and the birth and spread of the nation-state to all corners of the globe. In short, all of modern civilization occurred within the Holocene. In this context, the foundation for the current system of nation-states rests in part on a common assumption that the baseline climatic and natural-resource conditions present until today will generally continue. The flaw in this assumption is that atmospheric conditions, due to human activity, have shifted in an unprecedented way since the mid-20th century, and are changing rapidly. This phenomenon, coupled with massive demographic changes, has led some to assert that that the Earth may have entered a new epoch called the "Anthropocene."[5] The rapid changes inherent in this epoch could stress the very foundations of the modern nation-state system.

The nature of the threat

Regardless of whether or not the Earth is, indeed, in a new epoch, the influence of rapid climatic change on natural resources must be factored into our understanding of state fragility, state sovereignty, and the world order that rests on that sovereignty. This includes rising sea levels and an increase in the frequency and severity of extreme weather events, which will increase stresses on the critical resources underpinning

national security - water, food, transport, and energy systems. If left unmanaged, these pressures can decimate livelihoods and contribute to a broad range of destabilizing trends within states, including population displacements, migration, political unrest,[6] state fragility, internal conflict, and, potentially, state collapse.[7] The transboundary nature of some climate impacts such as melting sea ice and migrating fish stocks in contested waters[8], can also increase the likelihood of conflict between states. [9]Therefore, the threat comes not from climate change itself, but rather, from how these changes interact with the existing security landscape – including the ability or inability of governments to effectively manage rapid change, ensure security and prosperity for their publics, and maintain their legitimacy.

The six erosions of state sovereignty

State sovereignty, in the modern sense, is built on both a state's output and input legitimacy.[10] Output legitimacy involves a state's ability to meet its citizens' demands for basic resources or prosperity (e.g., food, water, energy, employment), while input legitimacy involves a state's ability to offer its citizens a say in how they are governed (e.g. a vote and legal recourse). Climate change, by compromising a state's ability to provide basic resources to its population, can significantly erode its output legitimacy. This erosion can contribute to state fragility and state failure, which, in turn, has implications for regional and international insecurity.[11] Cumulatively, these risks can significantly challenge a world order built on an international system of cooperating sovereign states. That challenge derives from the contribution of climate change to six key phenomena:

1 Catch-22 states;
2 Brittle states;
3 Fragile states;
4 Disputed zones among states;
5 Disappearing states;
6 Non-state actors.

1. Catch-22 states

As natural resources within the territory of nations are strained, modern states have often turned to the global market to meet the difference between their capacity to provide food, water, and energy, and the demands of their populations. However, the global market is increasingly vulnerable to price fluctuations driven in part by an increase in the frequency and intensity of extreme weather events.[12] This presents a catch-22 for resource-stressed nations. Syria and Egypt are instructive examples.

Prior to the country's ongoing civil war, the al-Assad regime in Syria prided itself on being one of the few Arab nations to produce a significant percentage of its wheat locally, as

well as lucrative cash crops such as cotton, despite the water-intensity of those pursuits.[13] However, these crops were challenged by phenomena linked to climate change: multi-decade winter precipitation decline and the worst drought in Syria's recorded history, from 2007 to 2010.[14]. Population pressures and inefficient agricultural practices, such as flood irrigation, dramatically depleted the country's water table to a critical level.[15] These dynamics contributed to agricultural and pastoral devastation across Syria, and the displacement of nearly two million people. The al-Assad regime's ideal of greater self-sufficiency, which diminished the country's dependence on the global food market, was ultimately unsustainable due to local climatic, natural resource, and infrastructural conditions. Poor political decisions made by the regime, including mismanagement of natural resource, accelerated Syria's transition from relative stability to being one of the most conflict-ridden states in the world

The global food market has also been buffeted by climate change, making overdependence on it a risky venture. Egypt, like many of its neighbors, is one of the most highly dependent countries on the global wheat market.[16] In 2010, major drought and heat-wave events in China and Russia — the events in Russia explicitly connected to climate change by recent studies — devastated local wheat harvests, driving China and Russia to panic buy extraordinary quantities of wheat on the global market.[17] This was a major factor in the 300 percent price increase for bread in Egypt between 2010 and 2011.[18] Egyptian bread subsidy policies were unable to bring the price down in many rural areas.[19] While protests were occurring in Cairo and other cities, the appeal of the revolutionary movement in Egypt broadened to the countryside, where at least three major food riots occurred in 2011.[20]

Other nations in the Middle East, North Africa, Central Asia, and elsewhere are already facing a similar catch-22 situation, wherein both local agricultural production and dependence on the global food market are not optimal. If climatic and demographic projections continue along current trends, the number of states facing this catch-22 dilemma could increase.[21]

2. Brittle states

The security landscape hosts a number of seemingly stable nation-states that are nevertheless quite vulnerable under the surface from a resource perspective. In "brittle states," as opposed to fragile ones, the appearance of stability — due to either the imperviousness of such states to outside inquiry or ignorance of the role of natural resource vulnerabilities in contributing to political unrest — can lead analysts and policymakers to fail to anticipate fragilities and make ill-informed political, economic, and natural resource management choices.[22] One might also refer to these cases as "Potemkin Village" states — stable only on the surface. Brittle states may score relatively high in "state fragility indices" when compared with those more widely considered "fragile" or "failed."[23] These indices focus primarily on social, political, and economic circumstances,

often underestimating or excluding natural resource vulnerabilities that could render the body politic far more fragile.[24] For example, merely days prior to revolution erupting in Syria in 2011, political analysts identified the country as stable in comparison to its Middle Eastern and North African neighbors.[25] A late 2010 assessment by the Obama Administration concluded that Syria and Saudi Arabia were the states in the region "least likely" to experience political turmoil in the wake of unrest in Tunisia, Egypt, and Libya.[26] Generally missing from the analysis of Syria's stability were significant natural resource vulnerabilities, exacerbated by three decades of climate-induced precipitation decline and natural resource mismanagement.[27]

Prior to the events of the "Arab Awakening," Egypt was also considered a generally stable nation.[28] In addition to vulnerabilities related to dependence on the global wheat market, Egypt's internal natural resource picture suggests a brittleness. A combination of factors—including sea level rise, the over extraction of water from coastal aquifers, and the sharing of Nile waters with neighboring states—has left the already low-lying Nile Delta in a precarious situation. The Delta is heavily populated, containing many of Egypt's major cities and the vast majority of its population. Thirty percent of Egypt's labor force works in the agricultural sector, mostly in the Delta and Mediterranean coast, which are responsible for 30-40 percent of the country's total agricultural production. That production could be devastated by increases in saltwater intrusion exacerbated by rising sea levels.[29] Coupled with the vulnerability of Egypt's population to global food price shocks, failure to address rising sea levels and the Nile Delta's health, could contribute to the erosion of the legitimacy and resiliency of current and future Egyptian governments.[30]

Other nations, such as Saudi Arabia, while not ranking high in measurements of state fragility, are both heavily dependent on a volatile global food market and likely to experience precipitation decline and dangerous heat levels as a result of climate change.[31] Coupled with ethnic, demographic, and political pressures, climate change and water insecurity could threaten Saudi Arabia's stability.[32] Other nations with seemingly stable institutions, yet serious natural resource vulnerabilities under the surface, include Iran — which is suffering from many of the same climatic, water, and food security pressures as Syria — and North Korea, which is very resource poor and increasingly vulnerable to a changing climate.[33]

3. Fragile states

Climate change also increases the fragility of already fragile states. The populations of nations that are poorly governed and resource-stressed are likely to be among the hardest-hit. Climate impacts on water systems, for example, even challenge nations with robust institutions like the United States. States with weak institutions are likely to fare worse. A great number of fragile states — such as Sudan, Ethiopia, and the Central African Republic in Africa; Pakistan and Bangladesh in South Asia; and Yemen and Libya — are all projected to experience some of the most dramatic effects of climate change in terms of rainfall variability and sea level rise.[34]

In the absence of significant adaptation efforts, a slowing of the rate of climatic change, or significant improvements in natural resource governance, such nations are likely to become even more fragile than they already are, potentially increasing the incidence of state failure. As states fail, refugee crises are also likely to increase in frequency and scale. Nationalistic responses to such dynamics, in Europe, for example, can place significant strains on those institutions intended to maintain regional order, such as the European Union.[35]

4. Disputed zones among states

Climate change can also increase the possibility of tensions between major powers over zones subject to competing territorial claims, which could have important implications for world order. Two clear examples of this disputed zone/climate change nexus are the South China Sea and the Arctic Ocean. The South China Sea is one of the most critical geostrategic choke points in the world. Seafaring vessels carry $1.2 billion of U.S. trade through its waters annually.[36] Sovereignty over significant areas of the China Sea is bitterly disputed by adjacent countries, while the United States and China have competed over its control for some time — with the U.S. viewing China's expansionist territorial claims to the sea as a threat to its interests in the Asia-Pacific region and to the security of key allies and partners.[37] Overlaid on this tense geostrategic environment is a warming ocean. Coupled with over-fishing, this phenomenon is driving fish stocks to migrate northward into colder (and contested) waters.[38] As the populations of small nations bordering the sea, such as Vietnam, are highly dependent on its fish stocks as a major source of protein, fishing fleets are likely to venture farther north, and with greater frequency, into zones that are subject to competing claims between their nation of origin, China, and the United States.[39] Such a dynamic could increase the likelihood and number of regional security disputes in the future.

On the other hand, the Arctic is host to extraordinary cooperation between nations, in a region that could have easily become a Wild West of water and ice. This cooperation may be due to successful intergovernmental regional institutions, such as the Arctic Council, and a desire among nations involved in the Arctic to maintain stable sea lanes for global economic commerce. However, due to rapidly melting ice, the Arctic is changing significantly. This has already had a measurable effect on the security landscape in the Arctic.[40] Since Russia's incursion into Crimea and eastern Ukraine, each member state of the North Atlantic Treaty Organization (NATO) has suspended all forms of military cooperation with Russia, including in the previously apolitical zone of "military cooperation" in the Arctic. In a context of possibly greater interaction between Arctic nations (due to melting ice), but less cooperation due to diplomatic conflicts elsewhere in the world, the probability of heightened tensions between major powers increases. While the current probability of conflict in the Arctic is low, the future is uncertain due to a rapidly changing physical and geopolitical landscape.[41]

5. Disappearing states

Rising sea levels will also lead to the eventual disappearance of certain low-lying states as well as the loss of significant territory for other states. This includes island states, such as the Maldives, and large swaths of countries, such as the low-lying coastal zones of Bangladesh.[42] For small island nations, climate change and sea level rise present an existential threat (and thus the possibility of a total loss of sovereignty). The international community has no experience in managing the disappearance of nations as a result of environmental processes.[43] In fact, there are no international legal norms designed to account for such an eventuality — including no formal recognition of "climate refugees" or "environmental refugees."[44] The loss of entire states, or large zones within states, may contribute to a mass increase in stateless peoples, which could present a humanitarian, political, and security crisis of the highest order. The full nature of the consequences of such an event are not broadly understood, and given the rapid rate of sea level rise, this unknown represents a challenge to the current world order.

6. Nonstate actors

As climate change contributes to water and food insecurity and increases the likelihood of state failure and conflict, it is likely that nonstate actors with grievances against the state will take advantage of the loss of state legitimacy and the expansion of ungoverned spaces to gain power and leverage.[45] These expansions of ungoverned spaces may include an increase in organized criminal entities that engage in natural resource provision and a potential increase in the number and strength of nonstate actors who may ideologically reject the legitimacy of the states they operate in.[46] There is a wide and deep literature demonstrating the proliferation of nonstate actors in environments where states are weak and unable to provide food and water.[47] Today, Syria and Iraq are strong examples of this dynamic, given climatic projections for the region as well as the water insecurity, political fragmentation, and strength of terrorist organizations within their borders. As Dr. Marcus King notes, given that water resources are scarce, nonstate actors — including international terrorist organizations such as the Islamic State (IS) — are increasingly seizing such resources and using them as leverage against adversaries and as weapons against populations they wish to terrorize.[48] In the future, such leverage may be utilized to further erode the legitimacy of the state.[49] This is not to say that climate change causes terrorism. Rather, climate change can place additional strains on resource security in such a way that may contribute to an increase in the power of such nonstate actors.

Managing a changing order

The cumulative effect of climate change contributions to the erosion of state legitimacy may be far more significant than is currently appreciated. By placing strains on the

resources necessary for the viability of the nation-state system and the well-being of its populations, and by physically changing key geostrategic environments, climate change presents a threat to global security. In the face of such far-reaching implications, policies designed to address climate change cannot be fully commensurate to the threat if they are formulated primarily or exclusively in niche institutions. National governments, as well as regional and international security institutions will need to integrate the effects of climate change into their strategies, plans, and operations, and shift resources accordingly. Improving, augmenting, and possibly even creating new governance structures for addressing climate change may also be necessary for maintaining a stable world order.

Notes

1 This article is an abridged version of: Francesco Femia & Caitlin E. Werrell, "Climate Change, the Erosion of State Sovereignty, and World Order," The Brown Journal of World Affairs, Volume XXII, Issue II, Spring/ Summer 2016, pp 221-235

2 Co-Founders and Presidents, The Center for Climate and Security.

3 Mike Walker et al., "Formal Definition and Dating of the GSSP (Global Stratotype Section and Point) for the Base of the Holocene Using the Greenland NGRIP Ice Core, and Selected Auxiliary Records," *Journal of Quaternary Science* 24, no. 1 (2009): 3–17. doi:10.1002/jqs.1227.

4 J. R. Petit et al., "Climate and Atmospheric History of the Past 420,000 Years from the Vostok Ice Core, Antarctica," *Nature* 399 (June 1999): 429–36.

5 Colin N. Waters et al., "The Anthropocene Is Functionally and Stratigraphically Distinct from the Holocene," *Science* 351, no. 6269 (2016): http://science.sciencemag.org/content/351/6269/aad2622

6 Michael McElroy and D. James Baker, *Climate Extremes: Recent Trends with Implications for National Security* (Cambridge, MA: Harvard University Center for the Environment, 2012).

7 Rüttinger et al., *A New Climate for Peace.*

8 Patrick M. Cronin, ed., *Cooperation from Strength: The United States, China and the South China Sea* (Washington, DC: Center for New American Security, 2012); and Elizabeth Rosenberg, David Titley, and Alexander Wiker, "Arctic 2015 and Beyond: A Strategy for U.S. Leadership in the High North," Policy Brief (Washington, DC: Center for New American Security, December 2014).

9 W. Neil Adger et al., "Human Security," in *IPCC Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, United Kingdom and New York: Cambridge University Press, 2014), 755–91, http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Chap12_FINAL.pdf.

10 Vivien A. Schmidt, "Democracy and Legitimacy in the European Union," in *The Oxford Handbook of the European Union*, ed. Erik Jones, Anand Menon, and Stephen Weatherill (Oxford: Oxford University Press, 2012).

11 Ibid.

12 Michael B. Kelley, "Emerging Markets Could Be Devastated By A Literal Perfect Storm," *Business Insider*, March 6, 2013, accessed at http://www.businessinsider.com/emerging-markets-vulnerable-to-weather-2013-3.

13 Francesco Femia and Caitlin E. Werrell, "Syria: Climate Change, Drought and Social Unrest," *The Center for Climate & Security*, February 29, 2012.

14 Martin Hoerling et al., "On the Increased Frequency of Mediterranean Drought," *Journal of Climate* 25, no. 6 (2012): 2146–61.

15 Colin P. Kelley et al., "Climate Change in the Fertile Crescent and Implications of the Recent Syrian Drought," *Proceedings of the National Academy of Sciences* 112, no. 11 (2015): 3241–46.

16 Troy Sternberg, "Chinese Drought, Wheat, and the Egyptian Uprising: How a Localized Hazard Became Globalized," in "The Arab Spring and Climate Change," ed. Caitlin E. Werrell and Francesco Femia (Washington, DC: Center for Climate and Security, Stimson Center, Center for American Progress, February 2013).

17 F. E. L. Otto et al., "Reconciling Two Approaches to Attribution of the 2010 Russian Heat Wave," *Geophysical Research Letters* 39, no. 4 (2012); Stefan Rahmstorf and Dim Coumou, "Increase of Extreme Events in a Warming World," *Proceedings of the National Academy of Sciences* 108, no. 44 (2011): 17905–9; Troy Sternberg, "Chinese Drought, Bread and the Arab Spring," *Applied Geography* 34 (May 2012): 519–24.

18 Sternberg, "Chinese Drought, Wheat, and the Egyptian Uprising."

19 Sarah Johnstone and Jeffrey Mazo, "Global Warming and the Arab Spring," in "The Arab Spring and Climate Change," ed. Caitlin E. Werrell and Francesco Femia (Washington, D.C: Center for Climate and Security, Stimson Center, Center for American Progress, February 2013).

20 Sternberg, "Chinese Drought, Wheat, and the Egyptian Uprising."

21 Foad Al Harazi, "Future Impact of Climate Change Visible Now in Yemen," *World Bank*, November 24, 2014, accessed at http://www.worldbank.org/en/news/feature/2014/11/24/future-impact-of-climate-change-visible-now-in-yemen.

22 Herbert Obinger, Stephan Leibfried, and Francis G. Castles, Federalism and the Welfare State: New World and European Experiences (Cambridge: Cambridge University Press, 2005).

23 J. J. Messner et al., *Fragile States Index 2015* (Washington, DC: The Fund For Peace, 2015).

24 Caitlin E. Werrell, Francesco Femia, and Troy Sternberg, "Did We See It Coming?: State Fragility, Climate

Vulnerability, and the Uprisings in Syria and Egypt," *SAIS Review of International Affairs* 35, no. 1 (2015): 29–46.

25 A.L. Butters, "Why the Arab Democracy Wave Is Unlikely to Reach Syria—Yet," *Time*, February 4, 2011.

26 Jim Mann, *The Obamians: The Struggle inside the White House to Redefine American Power* (New York: Penguin Books, 2012).

27 Werrell, Femia, and Sternberg, "Did We See It Coming?"

28 The Fund for Peace, *Failed States Index 2010* (Washington, DC: The Fund for Peace, 2010).

29 Francesco Femia and Caitlin E. Werrell, *Egypt's Political Transition and the Rising Sea: An Opportunity for Reform*, Briefer no. 7 (Washington, DC: Center for Climate and Security, January 16, 2012).

30 Sternberg, "Chinese Drought, Wheat, and the Egyptian Uprising."

31 Messner et al., *Fragile States Index 2015*; Chatham House, *Global Food Insecurity and Implications for Saudi Arabia* (London: Chatham House, April 29, 2013).

32 John Hannah, "It's Time for the United States to Start Worrying About a Saudi Collapse," *Foreign Policy*, October 7, 2015.

33 Francesco Femia and Caitlin E. Werrell, *Eye on Iran: Lake Urmia, Water, Climate and Security in a Volatile Region*, Breifer no. 10 (Washington, DC: Center for Climate and Security, February 27, 2012); Benjamin Luke Habib, "The Implications of Climate Variability for North Korean Regime Stability," *International Journal of Climate Change: Impacts and Responses* 1, no. 1 (2009): 83–104.

34 Messner et al., *Fragile States Index 2015*; Intergovernmental Panel on Climate Change, "Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change" in *Climate Change 2014*: Mitigation of Climate Change (Cambridge and New York: Cambridge University Press, 2014).

35 Alastair MacDonald and Noah Barkin, "European Leaders Fear The Refugee Crisis Will Tear The E.U Apart," *Huffington Post*, January 18, 2016.

36 Cronin, *Cooperation from Strength*.

37 Ibid.

38 Marcus DuBois King, "Climate Change and Vietnamese Fisheries: Opportunities for Conflict Prevention," in "The U.S. Asia-Pacific Rebalance, National Security and Climate Change," ed. Caitlin Werrell and Francesco Femia (Washington, DC: Center for Climate and Security, 2015), 55–63.

39 Caitlin E. Werrell and Francesco Femia, eds., *The U.S. Asia-Pacific Rebalance, National Security and Climate Change* (Washington, DC Center for Climate and Security, 2015.

40 Uri Friedman, "The Arctic: Where the U.S. and Russia Could Square Off Next," *Atlantic Monthly*, March 28, 2014.

41 Timothy C. Gallaudet, *Charting The Arctic: Security, Economic, and Resource Opportunities* (Joint Subcommittee Hearing, Committee on Foreign Affairs, U.S. House of Representatives, Subcommittee on Europe, Eurasia, and Emerging Threats and Subcommittee on the Western Hemisphere, November 17, 2015.

42 Yasuaki Hijioka, Erda Lin, and Joy Jacqueline Pereira, "Chapter 24: Asia," in *Climate Change 2014: Impacts, Adaptation, and Vulnerability: IPCC 5th Assessment Report* (Cambridge and New York: Cambridge University Press, 2014).

43 Jenny Grote Stoutenburg, *Disappearing Island States in International Law* (Leiden, The Netherlands: BRILL, 2015).

44 Benjamin Glahn, "'Climate Refugees'? Addressing the International Legal Gaps," *International Bar Association,* June 2009, http://www.ibanet.org/Article/Detail.aspx?ArticleUid=B51C02C1-3C27-4AE3-B4C4-7E350EB0F442.

45 Rüttinger et al., *A New Climate for Peace*; Peter H. Gleick, "Water and Terrorism," *Water Policy* 8, no. 6 (2006): 481–503.

46 Tim Boekhout van Solinge, "The Illegal Exploitation of Natural Resources," in *The Oxford Handbook of Organized Crime*, ed. Letizia Paoli (Oxford: Oxford University Press, 2014).

47 Todd Sandler, "The Analytical Study of Terrorism Taking Stock," *Journal of Peace Research* 51, no. 2 (2014): 257–71.

48 Marcus DuBois King,"The Weaponization of Water in Syria and Iraq," Washington Quarterly 38, no. 4 (Winter 2016): 153–69.

49 Ibid.

Water Towers: Security Risks in a Changing Climate

Troy Sternberg[1]

Since the Boutros Boutros Ghali, then Secretary General of the United Nations stated that the next war in the Middle East will be over water, not politics, the global community has focused on water flashpoints, particularly in the Middle East.[2] But examining micro- to meso-scale dynamics has confined thinking to rivers, aquifers and watersheds at national levels. While important, discussion has often ignored the mega-scale threat of human and climate changes[3] to the world's mountain 'water towers' [4] and the resultant implications to security and human well-being. For example: two billion people depend on water originating on the Tibetan Plateau[5]. Hundreds of millions more drink from global water towers, including the massive Andes, Rockies, Tien Shan, Caucasus and Alps to the more modest Ethiopian and Guinean Highlands. In each, climate change affects glaciers, water resources and runoff[6]. If it were only a matter of harnessing water from a nation's territorial mountain, the issue would be structural; the complication comes when water flows through several states. Riparian nations stress natural, human and economic rights to water that crosses their realm, yet without physical control, states remain vulnerable to upstream users. This gives a hegemonic dynamic to control of water towers with significant implications for national and regional security.

Water Towers as regional and global risks

The key link between water towers and security lies in their transboundary nature. In most instances massive mountain systems stretch beyond national borders. Thus factors affecting water dynamics have a cascading effect on riparian states that rivers traverse.[7] Any change upstream has a potential corresponding impact downstream. This global

phenomenon affects 4 billion people across the continents (Table 1)[8]. Consider the countries that share mountain water resources – many riverine environments are today's conflict flashpoints[9]. Think of the sources of the Euphrates, Tigris and Jordan rivers in the Middle East, the Nile and Himalayan rivers flowing through India and China and the potential for clashes over water rights. Contrast this with the International Commission for the Protection of the Danube River where 14 signatory nations have agreed to share and protect the river.

Table 1: [10, 11]
Mountain contribution to total water discharge; relative size of mountain area

River	Discharge %	Area %	Countries
Orange	100	42	Lesotho, South Africa
Colorado	100	46	US, Mexico
Rio Negro	100	60	Colombia, Venezuela, Brazil
Amu Darya	98	68	Tajikistan, Afghanistan, Turkmenistan, Uzbekistan
Nile	93	44	Ethiopia, Sudan, Egypt, Uganda, South Sudan, etc.
Euphrates	85	22	Turkey, Syria, Iraq
Tigris	80	41	Turkey, Syria, Iraq
Indus	76	31	China, Pakistan
Niger	58	11	Guinea, Mali, Niger, Benin, Nigeria
Rhine	49	22	Switzerland, Austria, Germany, France, Netherlands
Mekong	34	48	China, Myanmar, Laos, Thailand, Cambodia, Vietnam
Danube	32	16	Germany, Austria, Hungary, Serbia, Romania, etc.

The table emphasizes how water tower dynamics and issues are shared around the world. Mountain glaciers are the source of major rivers[12], have geographical distribution, diverse political contexts, and confront similar challenges. Foremost are climate change, population, human action and extreme events. Processes are linked by cause, impact and outcome in both environmental and social spheres as water towers serve half of humanity (Table 2). These forces mean that changes to water towers affect well-being and security at regional and continental levels, not just at national scales.

Table 2: [13, 14] **Water Tower Facts**

Serves 50% global population
>80+% runoff in river basins
>50% area supplies downstream water
Mountains cover 25% land surface
Provides hydropower, domestic, industry,
Source of crops - potatoes, maize, barley, etc.

As with so many climate and security issues today, a discussion of water towers starts in China as the *de facto* potentate of the Tibetan plateau[15]. Its thirsty population (22% of the world's population, 7% of the water) needs increasing water supply for domestic, agriculture and industrial growth. The country's major rivers are heavily tapped; at times the Yellow River no longer reaches the sea. The South to North Water Transfer projects come at great cost ($77-plus billion)[16] and uncertain effectiveness. Chinese scientists have considered a Lake Baikal to Beijing water pipeline as well as inter-basin water transfer schemes, dams, diversions and desalination to increase water supply. No wonder that the Politburo seeks to maximize water resources on the Tibetan Plateau[17]. In keeping with their communist-era tradition, the government focuses on domestic exigencies rather than cross-border concerns or regional relationships. When in 2013 the Chinese mentioned diverting the Yarlung Tsangpo/Brahamputra from the Tibetan border region, India was apoplectic[18]. The idea was presented as an innocent refill for the Yangtze (imagine the physical implications there). The statement that nuclear explosions could be used to blast a passageway through the Himalayas conveys a threatening security message to the sub-continent downstream.

This issue reflects the anger, volatility and folly a discussion of manipulating water towers can generate. India's unsurprising response was that any diversion would be an act of aggression. The potential for the two most populous and nuclear-equipped nations going to war dwarfs anything the Middle East can present. However, when in 2016 India announced its plans to divert parts of the Brahmaputra there was no concern for downstream users in Bangladesh[19] – apparently the country was too small, and without nuclear weapons, to be of much concern. In this way the future of water towers very much reflects a power game, both in terms of who is able to control and manipulate the water, and whether or not this actor can rebuff any challenge from downstream users.

Elusive Control of Water

The sheer power of water carves a path through landscapes leaving several practical issues for societies to contend with. Maps may show clear lines of national control but mountain territory is, by definition, notoriously rugged and a difficult geography in which to place "boots on the ground" Consider Pakistan and India's multi-decade skirmish over Kashmiri lines of control at 6,000 meters. While the Ganges, Irrawaddy, Salween and Mekong are sourced on the Tibetan Plateau, rivers have a way of meandering, bifurcating, joining and splitting on their journey to the ocean. This makes water hard to control and variable over time; consider that the Niger once flowed from the Guinea Highlands through Timbuktu. The very nature of water – fluid, heavy, unconfined, awkward to transport -- requires much infrastructure and great cost to move from source to end-user. These qualities and challenges mean that location is important for access and control. Upstream states have first-user advantage

on rivers, making downstream riparians subject to decisions and actions beyond their control. The process gives water a transboundary, political dynamic that can be cooperative (Danube) or contentious (Tigris, Mekong) and contributes to securitization and conflict. This can be exacerbated by major water projects that become "nation-building" exercises. Think of the significance Turkey attached to the Greater Anatolia Project[20] or China's self-importance about the 3 Gorges Dam when it was initiated in the 1980s. This leads to social and philosophical dimensions of water: can abstraction of water tower resources be justified physically, diplomatically, economically and to the long-term benefit of one or several state authorities?

Climate Change

So far the discussion has side-stepped the elephant in the water tower – climate change[21, 22]. Pandey (2017)[23] gives a sobering assessment of climate implications in the Himalayas where the recession of glaciers is part of a global trend. New techniques for assessment, such as the remote sensing, the Normalised Melt Index, cryospheric analysis and data-driven hydrological modelling, can identify changes in the world's water towers[24]. Climate impacts particularly affect water processes including glacial and snow melt, precipitation patterns, temperature and changing global weather dynamics[25] (Table 3). These factors will change downstream water availability, increase volatility and affect water resources and recharge along water basins both today and in the future as the volume of water stored in ice caps and permafrost decreases. The consequences for water access and food supply[26] are immense and a vital concern for poorer, agriculture-dependent societies as shifts in water resources affect populations, politics and security.

Dynamic water processes can become irreversible as climate and weather patterns are transformed. Decreased glacial mass, changes in albedo (surface reflection), timing and seasonality of precipitation, temperature variability, shifts in cloud cover and wind patterns may reinforce deleterious impacts[27]. For example, climate-influenced snow and ice cover has seen Glacier National Park (U.S.) decrease from 150 glaciers to today's remaining 25. This exemplifies the irreversibility of climate impacts on mountain systems. As frozen water sources are depleted they will not return on a human timescale. Such historically unprecedented change has corresponding impacts on living conditions and could threaten social stability and provoke state conflict over water resources.

Table 3: Climate Change Impact on Water Towers

Reduced glacial cover, mass
Affect weather patterns, seasonality
Temperature impacts streamflow
Decreases downstream runoff
Loss of water stored as permafrost
Increased glacial lakes
Increased extreme events - floods, debris flow, glacial lake outbursts
Impact soils, wetlands, water supply
Contributes to food shortages, loss of renewable energy, conflict
Disrupts transborder stability

Infrastructure

Mountain water towers and access to their transboundary rivers present a delicate balance between users. Water withdrawals from rivers are encouraged to serve local needs, predominantly for agriculture and domestic water supply. This is like sticking a straw in a glass and drawing out as much water as can be swallowed before others can drink. Until recently this had been hard to monitor, particularly if many straws were drinking from the river. Satellite data now provides new methods of identifying water flow and vegetation density, recording changes over time, and insight into national water regimes.

Infrastructure changes river patterns, flow, amount and access, benefiting upstream users to the detriment of downstream states. Most common are dams, including run-of-the-river dams that generate electricity but do not involve water retention. Large-scale dams have greater riverine impact in their ability to change and govern water amount and flow, provide vast storage, control discharge, timing, flooding and regularity. At the same time dams reduce or remove sediments from rivers as they are trapped in reservoirs, diminishing the natural benefit of nutrient replenishment downstream. River channelization is another impact, often involving straightening or deepening waterways for human convenience and profit – to increase boat and barge transport capacity and speed while neglecting potential detrimental effects as natural barriers to rapid water flow. Curves, meanders, fields and plants are eliminated in the name of efficiency. The problem, highlighted by 2005's Hurricane Katrina, is that in extreme events the astonishing power of great volumes of water overwhelms feeble man-made defenses to great human and economic cost. In transboundary environments water infrastructure exemplifies assertion of hegemonic rights and control.

Likelihood of Conflict

Variegated circumstances flowing from water towers draw together physical, social and environmental dynamics in such a way that if water resources are compromised, societies are at risk[28]. At this point the specter of national security becomes a concern; when essential resources upon which a country depends are damaged, the threat to human and social survival can potentially lead to conflict.[29, 30] The scenario is basic: < water = < agriculture = < food = livelihood stress and then directly to protest and civil unrest. Responses reflect power relations: can a state persuade or force an upriver abstractor to let water flow? If political resolution is not feasible, are local and state actors prepared for confrontation? Can pressure be brought to bear from state-to-state relations, from the international community, through the auspices of the United Nations, African Union, ASEAN or other trans-national organizations? In the above context it is unlikely the Mekong Delta countries have the political, economic or military power to change Chinese action, yet China may recognize that there can be a breaking point in state water manipulation. Conversely, the China-India scenario is more problematic and asks the question, "will states go to war over water?"

The idea of Mexicans, Bulgarians, Sudanese or Laotians commandeering naval vessels and heading upriver to attack an exploitive water usufruct is rather preposterous. Already waterways are manipulated, altered and reconfigured as perceptions and use of water are transformed. Indeed, development changes water needs as conception and presentation of state power and industrialization moves away from mega-projects toward technology. Instead of the 3 Gorges Dam and vast infrastructure representing state advancement, China now stresses its astronauts and high-tech industry. The role of water for agriculture continues to evolve as economic progress transforms how and where a society uses water. Today farming consumes ~ 65% of China's water while in India the rate remains >90%[31]. Other options – reuse, desalination, taking advantage of "virtual" water and making water delivery systems more efficient are ways to reduce riverine pressures and flashpoints.

Today's awareness of the value of water can have a salutary impact on transboundary water cooperation[32]. The Middle East, of all places, offers an example of collaboration replacing conflict. Driven by new desalination capacity, Jordan and Israel trade water, in the south and north, to the benefit of both countries. The process reflects a willingness to overcome political barriers for mutual advantage, reflected in the Danube River coalition.

Can this be replicated across the world's water towers?[33] Shared interests, alarm over domestic unrest, political realities, costs and fear of regional hostilities need to be continually discussed and balanced. Positively, water towers in the Americas, Europe and much of Africa, while presenting challenges, are not conflict-prone. This

reflects the ability or resignation of states in resolving or accepting de facto mountain water regimes. On a geo-political scale, powerful states infrequently share key water resources; a Russian, U.S. or China confrontation is unlikely, though an Indian-Chinese water-driven clash is conceivable. More likely are confrontations between large and small states and conflicts driven by population, demand for food and economic/ infrastructure differences.

Present dynamics and potentially unknown future crises will be influenced by climate change disrupting water resources[34]. Climate impacts present a clear risk to long-term water supply, while the capacity for a global response that is commensurate to the risk is less clear. At stake are human and national well-being and threats to sovereignty and security, both real and perceived. This makes water towers one of the vulnerable pillars of regional and global security that will test the world's ability to adapt and respond to changing climates and water resources via peaceful means.

Notes

1 Researcher, University of Oxford, School of Geography and Environment.

2 J. Selby, "The geopolitics of water in the Middle East: fantasies and realities." *Third World Quarterly* 26, no. 2 (2005): 329-349.

3 UNESCO, Our global water towers. (2014). Accessed at unesdoc.unesco.org/images/0023/ 002308/ 230850e.pdf

4 D. Viviroli, B. Messerli, B. Schädler and R. Weingartner. "Water towers in a changing world," *Mountains and climate change: From understanding to action* (2009). Accessed at www.fao. org/docrep/017/i2869e/i2869e00.pdf

5 UNESCO, "Mountains as the water towers of the world," Accessed at www.unesco.org/fileadmin/ MULTI MEDIA/.../SDGs_and_mountains_water_EN.pdf

6 A. Sorg, T. Bolch, M. Stoffel, O. Solomina, and M. Beniston. "Climate change impacts on glaciers and runoff in Tien Shan (Central Asia)." *Nature Climate Change* 2, no. 10 (2012): 725-731.

7 D. Viviroli, H. Dürr, B. Messerli, M. Meybeck and R. Weingartner. "Mountains of the world, water towers for humanity: Typology, mapping, and global significance." Water resources research, 43(7) (2007).

8 UNESCO, Our global water towers. (2014). Accessed at unesdoc.unesco.org/images/0023/ 002308/ 230850e.pdf

9 UNESCO, "Mountains as the water towers of the world," Accessed at www.unesco.org/fileadmin/ MULTI MEDIA/.../SDGs_and_mountains_water_EN.pdf

10 D. Viviroli, B. Messerli, B. Schädler and R. Weingartner. "Water towers in a changing world," *Mountains and climate change: From understanding to action* (2009). Accessed at www.fao. org/docrep/017/i2869e/i2869e00.pdf

11 D. Viviroli, H. Dürr, B. Messerli, M. Meybeck and R. Weingartner. "Mountains of the world, water towers for humanity: Typology, mapping, and global significance." Water resources research, 43(7) (2007).

12 UNESCO, Our global water towers. (2014). Accessed at unesdoc.unesco.org/images/0023/ 002308/ 230850e.pdf

13 Ibid.

14 UNESCO, "Mountains as the water towers of the world," Accessed at www.unesco.org/fileadmin/ MULTI MEDIA/.../SDGs_and_mountains_water_EN.pdf

15 K. Pomeranz, "Asia's unstable water tower: the politics, economics and ecology of Himalayan water projects." Asia policy 16 (2013): 4-10.

16 T. Sternberg, "Water megaprojects in deserts and drylands." *International Journal of Water Resources Development* 32, no. 2 (2016): 301-320.

17 D. Viviroli, B. Messerli, B. Schädler and R. Weingartner. "Water towers in a changing world," *Mountains and climate change: From understanding to action* (2009). Accessed at www.fao. org/docrep/017/i2869e/i2869e00.pdf

18 Chinese dams in Tibet raise hackles in India.. Washington Post, February 7, 2013. Accessed at www.washingtonpost.com/.../chinese.../2013/.../ee39fc7a-7133-11e2-ac36-3d8

19 India set to start massive project to divert Ganges and Brahmaputra rivers, May 18, 2016, *Guardian*, Accessed at www.theguardian.com/global-development/2016/may/18/india-set-to-start-massive -project-to-divert-ganges-and-brahmaputra-rivers

20 T. Sternberg, "Water megaprojects in deserts and drylands." *International Journal of Water Resources Development* 32, no. 2 (2016): 301-320.

21 UNESCO, Our global water towers. (2014). Accessed at unesdoc.unesco.org/images/0023/ 002308/230850e.pdf

22 W. Immerzeel, L.Van Beek, and M. Bierkens. "Climate change will affect the Asian water towers." *Science*, 328(5984) (2010):1382-1385.

23 P. Pandey, "Climate hazards in the Himalayan Region," *Climate Hazard Crises in Asian Societies and Environment*, T. Sternberg (ed) (2017). Routledge, Abingdon.

24 W. Immerzeel, L.Van Beek, and M. Bierkens. "Climate change will affect the Asian water towers." *Science*, 328(5984) (2010):1382-1385.

25 D. Viviroli, H. Dürr, B. Messerli, M. Meybeck and R. Weingartner. "Mountains of the world, water towers for humanity: Typology, mapping, and global significance." Water resources research, 43(7) (2007).

26 W. Immerzeel, L.Van Beek, and M. Bierkens. "Climate change will affect the Asian water towers." Science, 328(5984) (2010):1382-1385.

27 A. Sorg, T. Bolch, M. Stoffel, O. Solomina, and M. Beniston. "Climate change impacts on glaciers and runoff in Tien Shan (Central Asia)." *Nature Climate Change* 2, no. 10 (2012): 725-731.

28 D. Viviroli, H. Dürr, B. Messerli, M. Meybeck and R. Weingartner. "Mountains of the world, water towers for humanity: Typology, mapping, and global significance." Water resources research, 43(7) (2007).

29 UNESCO, "Mountains as the water towers of the world," Accessed at www.unesco.org/fileadmin/ MULTIMEDIA/.../SDGs_and_mountains_water_EN.pdf

30 D. Viviroli, H. Dürr, B. Messerli, M. Meybeck and R. Weingartner. "Mountains of the world, water towers for humanity: Typology, mapping, and global significance." Water resources research, 43(7) (2007).

31 K. Pomeranz, "Asia's unstable water tower: the politics, economics and ecology of Himalayan water projects." Asia policy 16 (2013): 4-10.

32 Ibid.

33 D. Viviroli, H. Dürr, B. Messerli, M. Meybeck and R. Weingartner. "Mountains of the world, water towers for humanity: Typology, mapping, and global significance." Water resources research, 43(7) (2007).

34 UNESCO, Our global water towers. (2014). Accessed at unesdoc.unesco.org/images/0023/ 002308/230850e.pdf

Atlantis 2.0: How Climate Change Could Make States Disappear – and What That Means for Global Security

Andrew Holland[1] and Esther Babson[2]

Introduction

In the Fourth Century B.C., Plato wrote of how the great city of Atlantis was submerged beneath the ocean as punishment by the gods for becoming corrupt and greedy. In Plato's telling, an advanced civilization was lost forever in a single day because its people had strayed from the will of the gods. Since then, the story – whether based in historical truth or only a lesson in morality – has captivated generations. Now, 2300 years later, the world may be facing a new Atlantis, as sea level rise – caused by climate change – is threatening to inundate civilizations again.

The threat is global, but it is not shared equally. Like most of the effects of climate change, those most harmed by it are the populations with the fewest resources. At first, the greatest impacts will be felt by those living on low-lying islands like Kiribati and the Marshall Islands in the Pacific or the Maldives in the Indian Ocean. Life is difficult enough on these small islands, surrounded by the vastness of the ocean, without adding the challenges of sea level rise, more dangerous extreme weather, and the loss of food and fresh water resources.

Unlike Plato's Atlantis, however, the threat to small islands is easily predictable, if not preventable. Thankfully, we don't expect the islands to disappear in "a single day and night of misfortune" as Plato said of Atlantis' fate.[3] Allowing for some uncertainty, we know how sea level rise has accelerated on these islands over the past century, and we can predict the impacts. However, the effects will not be limited to only the small population of people living on islands. Alone, their economic and geopolitical

significance is miniscule. But, great powers remain interested in the strategic value of islands, and sea level rise will present a series of tests to them about how to manage conflicts. In the near term, the fate of small islands will present a series of "mini crises" about how and where to relocate peoples and societies, and who retains control of the resources they once owned. But, how the world manages those crises will offer a preview of how the world will respond to the far greater challenges that may lie decades hence; for one day, our civilization's great cities may face the same fate Atlantis did.

Climate Change is Already adding to Risk on Small Islands

The science leaves no question that the Earth's climate is changing, and the seas are rising as a consequence. Since 1951 temperatures have risen by at least .72ºC, and within the past decade, sea levels have risen at a rate of at least 2.8 mm/year.[4] While the entire globe will be impacted by climate change, small island states have become a "poster child" for climate change. For good reason: small island states with large populations near sea levels have already seen rates of sea level rise four times higher than global averages.[5]

This higher rate is due to a few factors, such as winds and gravity, that create regional differences in sea levels around the globe. For example, winds blowing in one direction move water the same way, creating higher sea levels in the direction the wind blows. A similar concept can be applied to ocean currents with a slower current leading to a "pile up" of water. Gravity also plays a major role in shaping sea levels. Whether they are polar ice sheets or a mountain range under the ocean, these features have additional gravitational force and, therefore, can draw more water towards them, creating a bump on the surface.[6] Finally, Earth's rotation creates a bulge around the equator as the middle of the Earth must move faster than the poles to complete a revolution in the same amount of time.[7]

All this means that different places around the world will see differing amounts of sea level rise, depending on location. Many of the most vulnerable islands are on the equator, leading to a naturally higher sea level to begin with. In the Maldives and Tuvalu, 100% of the population lives less than 16 feet above sea level.[8] Within the Marshall Islands and Kiribati, over 95% live below that mark.[9] With just 3 feet of sea level rise, the Maldives are likely to be submerged.[10]

Clearly, continued increases in sea level will have disastrous effects. Even if island nations aren't completely pushed beneath the waves, there are significant consequences. Islands are already seeing increased coastal inundation, erosion and even community displacement as the rising seas eat away at their land. Rising tides threaten to flood fresh water reserves with salt water. At the same time, a recent drought in the Marshall Islands caused more than 16,000 people to suffer from food and water shortages.[11]

The ocean itself is also affected by increasing temperatures. Growing ocean acidity and warming water have resulted in serious concern about the stability of coral reefs – and declining coral health undermines island communities because the reefs provide a source of food and income, as many are reliant on fish sales and tourism. Coral reefs have the added benefit of acting as a natural barrier against storm surges. Unfortunately, the impacts of a warmer ocean are already visible in many nations. Kiribati has seen unprecedented bleaching events with some islands seeing 100% coral mortality within the lagoons.[12]

Changes in human systems are equally apparent within many small island nations. Shifting biodiversity ranges, decreasing freshwater due to saltwater intrusion, changing precipitation patterns, more coastal development, and increasing incidence of diseases are all currently observed impacts.[13] Future trends are likely to only expand and multiply.

Prospective Risks for the Future

While modeling for islands is incredibly difficult due to scale, predicted trends are not optimistic. Even with a decrease in emissions today, the climate will continue to warm into the future. Predictions vary by region but studies suggest a 1.2°C to 2.3°C increase in temperatures by 2100.[14] Such an increase will result in serious consequences for the future of these islands. Estimates suggest that sea levels could rise up to 3 feet by 2090, submerging Kiribati, Tokelau, and Tuvalu.[15]

Many of the phenomena occurring already will accelerate.[16] In addition to rising seas, extreme precipitation is expected to increase, with both floods and droughts becoming more common. Increasing storm surges on already higher oceans will leave coastal communities at risk. If greenhouse gas (GHG) emissions continue to increase, the consequences will be far greater. A catastrophic melting of Greenland alone would result in about 6 feet of sea level rise, easily submerging entire cities and countries.[17]

As the impacts of climate change become more and more pronounced, secondary and tertiary consequences will begin to unfold. Due to the high dependence on reefs as a source of revenue, livelihoods will be threatened by the increasing level, temperature and acidity of oceans. Beyond loss of property and livelihood, one of the greatest concerns is complete loss of country. Rising seas will not submerge all islands, but many are severely threatened by even a meter of sea level rise. Where will these people go? What will happen to their submerged territory? And who will care enough to do anything about it?

What Happens to the Inhabitants?

Because of the inexorable nature of sea level rise, for many of the islands the best hope is not to protect the land with new sea walls, but to undertake controlled migration away from the islands. That will mean finding ways for people to move to new islands within the country or to new land in a new country. The president of Kiribati has announced an arrangement to buy land in Fiji.[18] That land is now being used to produce food for the inhabitants of Kiribati, but one day it could provide a new homeland. Such a controlled migration – which the Kiribati government calls "migration with dignity" – is unique in that it amounts to a government planning its country's demise. This process depends on foresight by the government, extra resources to buy the land, and a willing seller. Unfortunately, those aren't always paired in poor countries with weak governance.

Instead, what we should expect is more uncontrolled migration from island to island, to cities, and developed countries. This could play out similarly to Australia's asylum policies, which have pushed the country to turn boats away and detain migrants in offshore processing centers in countries such as Nauru and Papua New Guinea. It is a high-profile humanitarian disaster. When migrants are forced from their homes in an unplanned manner. The evidence suggests that this acts as a trauma that can undermine their long-term quality of life.[19]

Clearly, the better alternative is to attempt to replicate the Kiribati alternative as closely as possible. The society must debate how to adapt, whether through migration or coastline protection, then plan for it in an organized way and execute the plan together. Unfortunately, the realities of migration mean that decisions about when and where to migrate are usually made at the individual or family level. Seldom do entire communities pick up and move – and even when entire communities are physically removed, their lives are forever altered.

What Happens to the Resources?

Countries are afforded territorial rights to resources within their borders under customary international law. For islands, the relevant portion of law is the United Nations Convention on the Law of the Sea (UNCLOS), which codifies rights to resources within what is called an "Exclusive Economic Zone" (EEZ). These can be sub-sea deposits such as oil or natural gas, or resources such as fisheries that exist within the sea itself. Under Article 21 of UNCLOS, an island is entitled to an EEZ extending 200 miles into the sea, from a baseline point that is always above sea level. However, they must be considered an island and not just a "rock." A rock is defined as a place "which cannot sustain human habitation or economic life of their own."[20] Rocks, therefore, are not eligible to have a surrounding EEZ or territorial waters.

As the seas rise, we could see portions of countries change from "islands" under international law, to "rocks." They do not even need to become permanently submerged, only incapable of sustaining "human habitation or economic life." One potential scenario could be previously habitable islands losing their fresh water sources due to salt-water intrusion. Fortunately, it seems that the architects of the Convention gave some thought to the problem of shifting baselines, stating under Article 7 that, if a baseline is drawn in accordance with the rules of the Convention, and the lines are submitted and publicly disclosed, then the baselines are deemed permanent until changed.[21]

This would imply that the threat of sea level rise is not a threat to a nation's EEZ, so long as the nation remains. However, that raises a bigger question: if a country ceases to have any land, does it cease to be a country? And, if it ceases to be a country, what body retains the rights to the resources within the EEZ?

There is little precedent for this within international law. In the past, countries have willingly ceded their rights to territory, and their very existence, to another country; East Germany joined the Federal Republic of Germany to become a single German state in 1990. Or, is this a case more akin to the lawfully elected governments of many European states during World War II reconstituting themselves as "governments in exile" in London. If, for example, the government of Kiribati moved its people and leadership to its purchased land in Fiji, would it remain a full Member of the United Nations General Assembly? Would it maintain rights to the resources within its EEZ? Would it be a country? Or would these people simply be migrants to Fiji? The answers to questions like these are not obvious, and are fraught with moral and legal permutations.

These questions of international law would seem to make for an interesting academic exercise, aside from the fact that they present very real challenges for those living through these challenges.

The Geopolitical Implications of Lost Islands

In recent years, there has been a significant increase in funding from China to the South Pacific, an area traditionally dominated by aid from New Zealand, Australia, and the United States.[22] In 2014, Chinese President Xi Jinping made a state visit to Fiji to herald a closer relationship. China's efforts in the South China Sea show how much the country values sea borders and maritime control.

There are several geopolitical reasons for the great powers to compete over influence and access to resources.

The first is the global power of many voices speaking as one. Founded in 1990 as the voice of the Small Island Developing States in debates concerning climate change, the Alliance of Small Island States (AOSIS) has become a key voice in international climate forums, far outreaching their small population size and economic status. Together, the AOSIS includes 44 states, of which 39 are independent nations with voting status in the UN General Assembly. As China becomes a stronger global player, they have made efforts to portray themselves as a leader of developing countries. By courting favor with this bloc, China could bring a strong voice, with many General Assembly votes, to their side.

Secondly, great powers have recognized the military importance of island bases for centuries. Since the Second World War, the United States has built military infrastructure around the world on islands that now are at risk from sea level rise. Diego Garcia in the Indian Ocean, for example, is a critical logistics hub for the U.S. and U.K. militaries in the Middle East. On Kwajalein, an island in the Marshall Islands in the Pacific, the United States has invested billions of dollars into significant radar and ballistic missile defenses. Furthermore, both Kwajalein and Diego Garcia are used as ground stations assisting the operations of the Global Positioning System (GPS) navigational system.[23] A sea-level rise of several feet would cause the American military to lose geographically strategic outposts around the world.

Conclusion –A Risk not Limited to Small Islands

If the plight of the small nations of Kiribati, the Marshall Islands, or Tuvalu do not rise to the level of great geopolitical crisis, perhaps we should argue instead that they are the canaries in the coal mine. These problems are not unique to small, poor island nations. It is only that they will be forced to deal with them first. Already, in the United States, communities in coastal Louisiana and northern Alaska are reckoning with moving their entire towns because of sea level rise and coastal erosion. The costs are significant.

Not far down the line, however, the great metropolises of the world face similar threats. In the United States, cities such as Miami and New Orleans face an existential threat from sea level rise. Likewise, the low-lying Pearl River Delta region of China, around which China's economic powerhouses of Hong Kong, Shenzhen, and Guangzhou are clustered, could see vast swaths of its land submerged. This is not inevitable: prompt action to slow global warming and stop polar ice melt could save these cities. But, if the world fails at the relatively easy and predictable coordinated challenge of evacuating small islands, and solving their legal challenges, we should be pessimistic about solving the real challenges of Atlantis 2.0 that could come decades later.

Notes

1 Director of Studies and Senior Fellow for Energy and Climate, The American Security Project

2 Program Manager for Climate Security at the American Security Project

3 Plato, *Critias*, http://classics.mit.edu/Plato/critias.html.

4 J.H. Christensen, K. Krishna Kumar, E. Aldrian, .F.A. Cavalcanti, M. de Castro, W. Dong, P. Goswami, A. Hall, J.K. Kanyanga, A. Kitoh, J. Kossin, N.C. Lau, J. Renwick, D.B. Stephenson, S.-P. Xie and T. Zhou, *2013: Climate Phenomena and their Relevance for Future Regional Climate Change*. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

5 Climate & Development Knowledge Network, "The IPCC's Fifth Assessment Report: What's in it for Small Island Developing States?," Overseas Development Institute and Climate and Development Knowledge Network, 2014. http://cdkn.org/wp-content/uploads/2014/08/CDKN_IPCC_Whats_in_it_for_SIDS.pdf.

6 Michael Lemonick, "The Secret of Sea Level Rise: It Will Vary Greatly By Region," Yale Environment 360, March 22, 2010. Accessed at http://e360.yale.edu/feature/the_secret_of_sea_level_rise_it_will_vary_greatly_by_region/2255/.

7 Jeannie Evers(ed.), "Encyclopedia: Equator," National Geographic, 2011, http://nationalgeographic.org/encyclopedia/equator/.

8 United Nations Office of the High Representative for the Least Developed Countries, "Small Island Developing States (SIDS) Statistics," Accessed at http://unohrlls.org/custom-content/uploads/2013/09/Small-Island-Developing-States-Factsheet-2013-.pdf.

9 Ibid.

10 Brenda Ekwurzel, "Climate Hot Map: Republic of Maldives," Union of Concerned Scientists. Accessed at http://www.climatehotmap.org/global-warming-locations/republic-of-maldives.html.

11 Sally Adnrews, "Drought in the Marshall Islands," The Diplomat, February 16, 2016. Accessed at http://thediplomat.com/2016/02/drought-in-the-marshall-islands/.

12 L.A. Nurse, R.F. McLean, J. Agard, L.P. Briguglio, V. Duvat-Magnan, N. Pelesikoti, E. Tompkins, and A.Webb, 2014: Small islands. 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 [V.R. Barros, C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1613-1654.

13 Ibid.

14 Ibid.

15 Rob Taylor, "Pacific Islands Take Steps to Counter Rising Sea Levels," The Wall Street Journal, December 1, 2015. Accessed at http://www.wsj.com/articles/pacific-islands-take-steps-to-counter-rising-sea-levels-1448934453.

16 IPCC, 2014: *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 [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp1-32).

17 National Snow & Ice Data Center, "Quick Facts on Ice Sheets,. Accessed at https://nsidc.org/cryosphere/quickfacts/icesheets.html.

18 Laurence Caramel, "Besieged by the rising tides of climate change, Kiribati buys land in Fiji," The Guardian, June 30, 2014. Accessed at https://www.theguardian.com/environment/2014/jul/01/kiribati-climate-change-fiji-vanua-levu.

19 David Palmer & Kim Ward, "'Lost': listening to the voices and mental health needs of forced migrants in London," *Medicine, Conflict and Survival*, 23 (3) (07/01): 198-212.

20 United Nations Convention on the Law of the Sea, *Part VIII Regime of Islands: Article 121 Regime of Islands*. Accessed at http://www.un.org/depts/los/convention_agreements/texts/unclos/part8.htm.

21 Charles Di Leva & Sachiko Morita, "Maritime Rights of Coastal States and Climate Change: Should States Adapt to Submerged Boundaries?" Law & Development Working Paper Series no.5. Accessed at http://siteresources.worldbank.org/INTLAWJUSTICE/Resources/L&D_number5.pdf.

22 Grant Wyeth, "What to Make of China in the South Pacific?," The Diplomat, September 29, 2016. Accessed at http://thediplomat.com/2016/09/what-to-make-of-china-in-the-south-pacific/.

23 United States Air Force, "GPS," 2016. Accessed at http://www.gps.gov/systems/gps/control/.

Dire Straits: Strategically-Significant International Waterways in a Warming World

Adam H. Goldstein[1] and Constantine Samaras[2*]

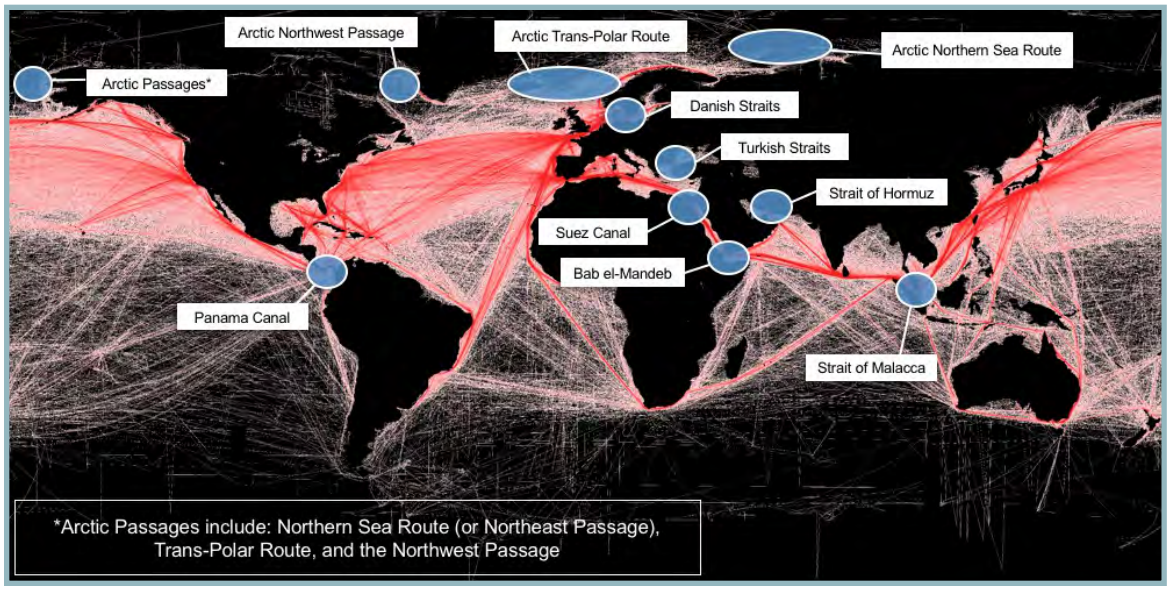
Introduction

While the oceans are vast, long-distance maritime traffic often flows through just a few passages due to confined geography and the desire to travel the shortest distance possible.[3] These marine chokepoints are critical to the continuous movement of goods around the world and are essential elements of the geostrategic landscape. These chokepoints include the Strait of Malacca (Malaysia), the Strait of Hormuz (Iran and the United Arab Emirates), the Suez Canal (Egypt), the Bab el-Mandeb Strait (between Yemen, Djibouti, and Eritrea), the Panama Canal, the Danish Straits, and the Turkish Straits.[4] Additionally, Arctic Ocean passages are likely to become important in the coming decades in a warming world due to climate change.

These maritime chokepoints may be viewed as a valuable and scarce natural resource, subject to increasing demand, finite supply, and few affordable alternatives (See Figure 1).[5] All greatly affect global trade dynamics through the capacity and size limitations they impose.[6] For instance, in 2013 the oil shipped through the Straits of Hormuz and Malacca alone represented a combined 36% of the total oil supplied globally, at 17 million and 15.2 million barrels per day, respectively.[7]

Each of these critically important passages face a dynamic host of challenges. Iran temporarily closed the Strait of Hormuz to maritime traffic through the use of mines as recently as the 1980s,[8] and it has recently increased the frequency of its "provocations" (as defined by the U.S. Central Command).[9] While instances of piracy in the Gulf of Aden (which connects to the Red Sea via the Bab el-Mandeb Strait) have declined precipitously since the mid-2000s, the Strait of Malacca and the surrounding waters

FIGURE 1



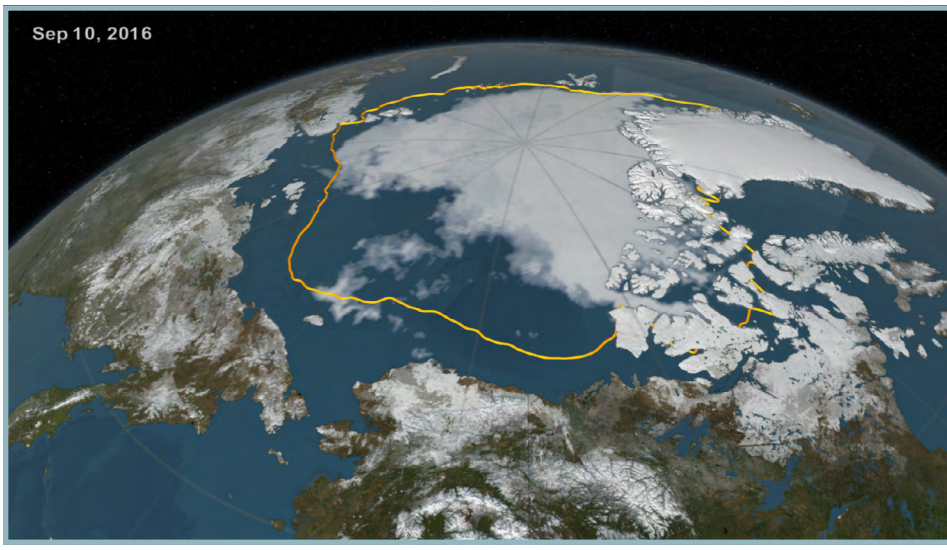
of Southeast Asia have experienced an almost 84% increase in the number of actual and attempted acts of piracy from 2011-2015, rising from 80 to 147 documented incidents, respectively.[10] The October 2016 guided missile attack by Houthi rebels on a UAE vessel near the Bab el-Mandeb Strait underscores the ongoing threat concerns surrounding strategically important maritime straits.[11] **All of these challenges are likely to grow in importance as the effects of global climate change alter the geophysical patterns undergirding national economies and patterns of life across significant segments of the world.** The impacts of climate change are likely to accelerate challenges in many of the regions with maritime chokepoints, and it is important to understand the range of impacts and plan for resiliency.

The 2014 U.S. Department of Defense Quadrennial Defense Review (QDR) described climate change as a "threat multiplier that will aggravate stressors abroad, such as poverty, environmental degradation, political instability, and social tensions – conditions that can enable terrorist activity and other forms of violence."[12] The National Intelligence Council's January 2017 Global Trends: Paradox of Progress report framed global climate change as a long-term force that will shift temperature, precipitation, and extreme weather event patterns in many regions, affecting agriculture and water supplies and accelerating pressure on fragile and failing states. Sea-level rise, coastal extreme events, and localized air pollution will also affect population patterns and infrastructure investment decisions. Climate change impacts are magnified by the increasing concentration of humans in climate-vulnerable locations, such as water-stressed, coastal, and urban areas. Combined, all of these factors will increase stress on social, economic, political, and security systems in many areas surrounding maritime chokepoints, as well as induce both geopolitical competition and cooperation.[13]

Maritime Straits with Potentially Major Climate Change Impacts

Some maritime straits will be directly affected by climate change through impacts to operations and availability. The Panama Canal is a major trading artery linking the Atlantic and Pacific Oceans, and the U.S. East Coast and Asia in particular. In June 2016, the Panama Canal Authority dedicated the "Third Set of Locks" project, which included deepening and widening the canal's channels. The expansion effectively doubles the overall capacity of the canal while also increasing the size limit for vessels utilizing the canal (from 5,000 to 12,500 Twenty Foot Equivalent Units (TEUs)). However, this newly expanded capacity is sensitive to the water levels in Panama's Gatun Lake, which are affected by El Niño meteorological events and may be affected by climate change.[14] The Panamanian National Environmental Authority (ANAM) in a 2013 application for funding identified the recent history and potential future risks associated with increased precipitation during the wet season and decreased precipitation during the dry season, especially during El Niño Southern Oscillation.[15] One recent study projected the Panama Canal region could experience increased rainfall and runoff from May to December (i.e. the wet season).[16] Climate-induced precipitation changes could result in changes in the expected shipping capacity of the expanded Panama Canal, both during droughts and flood events. However, additional understanding is needed to project climate impacts on the local scale, where relatively small (on the global scale) changes in precipitation and evaporation can have significant impacts. Inter-seasonal precipitation (i.e. wet season vs. dry season) is also an important area for future study as scientists and engineers assess climate change impacts on the Panama Canal watershed.

While future impacts in Panama are uncertain, scientists have observed significant impacts in the Arctic.[17] Perhaps no other shipping region will be affected by climate change more than the Arctic. Since World War II, the Arctic Ocean has been a major geopolitical theater of interest for the U.S. Bordered by the U.S., Canada, Russia, Greenland/Denmark, and Norway,[18] the ice-choked ocean was viewed as strategically important during the Cold War due to the regions surrounding it, rather than shipping or mineral wealth located on or under it. However, Arctic summer sea ice is diminishing rapidly and not rebounding as much as it used to in the winter months.[19] While the research community continues to investigate time frames and specific impacts, the 2014 National Climate Assessment assessed that summer Arctic Ocean sea ice is expected to "virtually disappear" by the middle of the century. This trend is expected to increase access for marine shipping, offshore mineral development and coastal erosion, and to significantly alter marine ecosystems.[20] Indeed, the burning of the petroleum products shipped through existing marine chokepoints is contributing to the change that is opening up a new waterway in the Arctic. [21]



Seasonal availability of the Northeast Passage (or Northern Sea Route) following Russia and Norway's coastline, the North Pole route passing through the center of the Arctic Ocean, and the Northwest Passage (tracking close to the U.S. and Canada's coastline) are expected to significantly expand the demand for Arctic Ocean maritime shipping.[22] These routes are thousands of nautical miles shorter than current routes and can offer substantial time and fuel savings for commercial shippers. A Northern Sea Route can save as much as two weeks on Asia to Europe routes (compared to present-day shipping via the Suez Canal), and also shorten routes from Europe to the U.S. West Coast.[23, 24]Among the Arctic passages, the Northern Sea Route is projected to be the most accessible shipping option in the near-term, with the trans-polar route becoming increasingly viable in the longer-term.[25]

In addition to its utility as a transport corridor, the Arctic Ocean contains vast mineral and resource wealth. As the Arctic warms, increases in access is likely to be unevenly distributed across the Arctic nations – Russia is projected to have the greatest percentage increase in access to its exclusive economic zone by late century.[26] According to the U.S. Geological Survey, the "Arctic continental shelves may constitute the geographically largest unexplored prospective area for petroleum remaining on Earth."[27] Increasing utilization of the Arctic Ocean as a result of global climate change may further strain international relations with Russia[28], while also increasing demands on border nations' emergency services and militaries due to increased shipping traffic in highly remote and more ice-prone waters. For example, increasing commercial utilization of the Arctic Ocean during the summer is likely to place new demands on the U.S. Coast Guard and Navy. In the past, ice and equipment failures had little impact on commercial vessels because there were few of them in the Arctic Ocean. However, when equipment fails or conditions unexpectedly worsen, as they inevitably will, it will often fall to the U.S. Coast Guard and Navy to provide aid. Both services have limited icebreaker capacity and a limited infrastructure in the Arctic region from which to project operational capability.[29]

Throughout most of the 19th Century the British and Russian empires engaged in "The Great Game," a diplomatic and political contest for influence and resources in Central and Southern Asia. A new Great Game may be about to unfold in the Arctic Ocean,

as vast mineral wealth and strategic trade routes are unlocked, potentially reshaping global trade between the eastern and western hemispheres. While some climate change impacts may not be apparent until the future, some are clearly already under way. An 820-foot (250m) cruise ship, the Crystal Serenity, traversed the Northwest Passage in the summer of 2016, opening the door for increased activity in the immediate future.[30] Existing ocean policy institutions are highly fragmented, with differentiated mandates for numerous separate international bodies managing human activity in international waters. A strategic approach to this complicated nexus of issues and actors is required.[31]

Maritime Straits with More Diffuse Climate Change Impacts

Many other regions with maritime straits will experience indirect effects from climate change. Climate and weather patterns have affected states throughout history, although the impacts have often only been recognized in retrospect. They exert pressures on a nation's economic, political, and social fabric. In 2016, the Office of the Director of National Intelligence assessed that climate change is likely to impact U.S. national security over the next 20 years through six major pathways:

> "Threats to the stability of countries;
> Heightened social and political tensions;
> Adverse effects on food prices and availability;
> Increased risks to human health;
> Negative impacts on investments and economic competitiveness; [and]
> Potential climate discontinuities and secondary surprises."[32]

These six pathways are likely to result in diverse impacts across the major maritime straits of the world. Regional stability threatening the free movement of energy commodities through the Strait of Hormuz is a perennial concern, given the narrow size of the passage, the potential for disruption, and the strait's importance to the global energy industry. In addition, the Danish Straits and Turkish Straits are increasingly important to Russian energy exports. Changes in geopolitical alliances, global oil demand trends, and Russian contributions to regional tensions could affect energy flows, investment, and security.

Yet the challenges aren't limited solely to energy transit routes, as disruptions to connected energy, food, and water systems can cascade across regions. Populations around global maritime straits, and in coastal states around the world, depend on access to the maritime commons for food and trade. Food supplies have also become more globalized -- many regions have increased their reliance on importing or exporting food, and the volume of agricultural exports has increased by 60 percent from 2000 to 2012.[33] Embedded in the growing amounts of food exports are non-renewable groundwater resources used in countries for irrigation.[34]

Divergent precipitation patterns are expected in many regions, whereby precipitation rates in already wet regions are expected to increase while precipitation rates in already dry regions are expected to decrease. Much of this decline in precipitation is expected to occur over the Middle East, northern Africa, western Central Asia, southern Africa, southern Europe, and the U.S. Southwest. For instance, between 80 and 90 percent of existing food supply in Gulf Cooperation Council states is imported,[35] and precipitation over Algeria, Saudi Arabia, and Iran is expected to decline by 2050.[36] This is likely to increase the scale and importance of food imports via maritime shipping, utilizing the Suez Canal, the Bab el-Mandeb Strait, and Strait of Hormuz. Twenty percent of the existing food imports to Gulf states originate in the Black Sea region, which is also threatened by rising temperatures and variability in precipitation. For food to travel from the Black Sea region to the Gulf, ships have to travel through the Turkish Straits, the Suez Canal, Bab el-Mandeb, and potentially the Straits of Hormuz.[37] Thus, challenges in one region can affect energy and food flows in other regions.

In addition, the degraded health of ocean ecosystems, rising water temperatures, and increasing population could lead to increased competition and degraded stability. The impacts of climate change are likely to stress both freshwater resources and freshwater fisheries,[38] resulting in a greater reliance on ocean fisheries that are also shifting geographically because of warming waters.[39] Changes in the productivity and geography of some ocean species and agricultural products could accelerate food security challenges in existing vulnerable states.[40] These issues are further exacerbated by overfishing and illegal fishing,[41] such as the challenges faced by fishermen in West Africa due to fishing by Chinese distant-water fishing vessels.[42] In the increasingly contested areas of South China Sea, fishing disputes between China and Vietnam have sometimes resulted in violence,[43] and shifting fish stocks could be a catalyst for further incidents. As waters warm and ocean traffic continues to increase, these trends may also place increasing stress on already fragile nation states across the world.

Finally, climate change impacts will stress the performance and integrity of the coastal infrastructure that enables trade and disaster response. The Intergovernmental Panel on Climate Change has assessed with high confidence that coastal infrastructure (e.g. railroads, ports, airports, roads, power and water supply, storm and sewage water management, etc.) are highly sensitive to a host of climatic and extreme weather events associated with climate change. Increased storm surges and precipitation events, on top of increased global mean sea levels, put additional infrastructure assets at risk of temporary or permanent flooding. Many industrial facilities and networks are periodically retrofitted in their original design location, meaning that siting locations made decades or even a century ago will continue to have an impact well into the future.[44]

While these direct impacts are more likely to be felt at the coast compared to the deep shipping channel, land-side facilities at ports and supporting facilities are facing major investments under climate change. For example, underinvestment and weather-related vulnerability threaten road and rail infrastructure in Russia and Ukraine, which are critical in moving agricultural products to ports.[45] Responding to disasters and extreme weather events will also require reliable access to coastal support facilities, which need to be resilient to the increasing impacts from climate change. An example of this effect is already occurring at Naval Station Norfolk, the world's largest naval station. Decades-old piers are being partially submerged every few months, requiring the utility conduits built into the piers to be shut off. This disrupts operations on the vessels docked at these piers, delaying maintenance work and potentially impairing operational readiness.[46] It is critical that investments in military and civilian coastal infrastructure maintain critical capabilities to respond to emergencies as conditions evolve[47], both for the U.S. and the international community.

Path Forward

The continuous and open flow of energy, food, and other goods through maritime straits is essential to improving economic opportunities and stability, and hence is in the interest of the global community. Many of the existing chokepoints will be stressed under the impacts of climate change, as well as with changes in trade demands, patterns, and alliances. It is important to further analyze and understand how maritime chokepoints, and the regions surrounding them, will be stressed under climate change. Policies and programs that strengthen state resilience to disruption will become increasingly important in regions with maritime straits. A growing and urbanizing population will increasingly rely on the maritime commons for food and trade, and initiatives that support food security in fragile states will be critical to stability. Equally important are the efforts to continue to diversify the sources and fuels used for energy to increase the resiliency of national economies to an oil price shock due to tensions at marine chokepoints. Also, because of the interconnected food, water, energy, and trade systems, disasters in one region can have global cascading impacts. Hence nations must enhance adaptive capacity to respond to disasters, which includes investing in resilient coastal infrastructure to maintain critical capabilities.

Global marine chokepoints have been critical geographies throughout history. The changing geostrategic landscape of the future and the role of climate in accelerating those changes means that these straits will likely remain key points of interest and power. The global community can reduce tensions in these chokepoints by undertaking investments and initiatives that increase resiliency to disruptions to food, energy, and water systems in a warming world.

Acknowledgements

All statements reflect our own views and not necessarily the opinions of any organization. We are grateful to Caitlin Werrell and Francesco Femia for helpful comments.

Notes

1 Graduate Research Assistant, Energy, Science, and Technology Policy Program, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15123 USA.

2 Assistant Professor, Department of Civil and Environmental Engineering, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15123 USA.
* Corresponding Author. Email: csamaras@cmu.edu Phone: +1.412.268.1658

3 Adapted from Grolltech. (2012, March 19). Shipping Routes. Accessed November 30, 2016, from https://commons.wikimedia.org/wiki/File:Shipping_routes_red_black.png.
This file is licensed under the Creative Commons Attribution-Share Alike 3.0 Unported license; it is free to share and remix with attribution and share alike.
The underlying research presented in the graphic was performed by: Halpern, B.S., et al. 2008. A Global Map of Human Impact on Marine Ecosystems. Science 319(5865):948-952. http://dx.doi.org/10.1126/science.1149345

4 Charles Emmerson and Paul Stevens. *Maritime choke points and the global energy system: charting a way forward.* Chatham House, 2012. Accessed at https://www.chathamhouse.org/sites/files/chathamhouse/public/Research/Energy%2C%20Environment%20and%20Development/bp0112_emmerson_stevens.pdf

5 Donna J. Nincic, "Sea Lane Security and U.S. Maritime Trade: Chokepoints as Scarce Resources", in *Globalization and Maritime Power*. Washington, D.C.: National Defense University Press, 2002, accessed at https://www.files.ethz.ch/isn/110803/fulltext.pdf

6 Jean-Paul Rodrigue, Claude Comtois, and Brian Slack. *The geography of transport systems*. New York: Routledge, accessed at https://people.hofstra.edu/geotrans/eng/ch1en/appl1en/ch1a2en.html

7 U.S. Energy Information Administration. *World Oil Transit Chokepoints*. November 10, 2014. Retrieved November 21, 2016, accessed at https://www.eia.gov/beta/international/analysis_includes/special_topics/World_Oil_Transit_Chokepoints/wotc.pdf

8 Ronald O'Rourke, "The Tanker War", U.S. Naval Institute Proceedings Magazine, 1988. Retrieved November 21, 2016, accessed at http://www.usni.org/magazines/proceedings/1988-05/tanker-war

9 David Brunnstrom, "Close encounters with Iran show need for rules of behaviour -U.S. Navy." Reuters. September 12, 2016. Retrieved November 21, 2016, accessed at http://uk.reuters.com/article/uk-usa-iran-navy-idUKKCN11I1VE

10 Table 1, ICC International Maritime Bureau. (2016). *Piracy and Armed Robbery Against Ships – 2015 Annual Report*. Retrieved November 21, 2016, accessed at http://www.hellenicshippingnews.com/wp-content/uploads/2016/02/2015-Annual-IMB-Piracy-Report-ABRIDGED.pdf

11 Sam LaGrone, "Officials: 3 U.S. Warships Off Yemen Following Attack on UAE Ship." *U.S. Naval Institute*. October 4, 2016. Retrieved November 21, 2016, accessed at https://news.usni.org/2016/10/04/official-3-u-s-warships-off-yemen-following-attack-uae-ship

12 Page 8, U.S. Department of Defense. (2014). *The 2014 Quadrennial Defense Review*. Accessed November 21, 2016, from http://archive.defense.gov/pubs/2014_Quadrennial_Defense_Review.pdf

13 Pages 21-22, National Intelligence Council. (2017). *Global Trends: Paradox of progress: A publication of the National Intelligence Council*. Retrieved January 16, 2017, from https://www.dni.gov/files/images/globalTrends/documents/GT-Main-Report.pdf

14 United Nations Office for Disaster Risk Reduction. (2016, June 28). *Easing impact of drought on the Panama Canal*. Retrieved November 22, 2016, accessed at https://www.unisdr.org/archive/49408

15 Panama National Environmental Authority. (2013, April). *Enhancing Resilience to Climate Change and Climate Variability in the Central Pacific Region of Panama*. Retrieved November 22, 2016, accessed at http://www.miambiente.gob.pa/images/stories/BibliotecaVirtualImg/CambioClimatico/Propuesta_de_Panama_al_FA_en.pdf

16 Panama National Environmental Authority. (2013, April). *Enhancing Resilience to Climate Change and Climate Variability in the Central Pacific Region of Panama*. Retrieved November 22, 2016, accessed at http://www.miambiente.gob.pa/images/stories/BibliotecaVirtualImg/CambioClimatico/Propuesta_de_Panama_al_FA_en.pdf

17 Jose Fábrega, Tosiyuki Nakaegawa, Reinhardt Pinzón, Keisuke Nakayama, and Osamu Arakawa. "Hydroclimate projections for Panama in the late 21st Century." *Hydrological Research Letters* 7, no. 2 (2013): 23-29.

18 Jeff Tollefson, "Huge Arctic report ups estimates of sea-level rise", *Nature*. April 28, 2017, accessed at http://www.nature.com/news/huge-arctic-report-ups-estimates-of-sea-level-rise-1.21911

19 NASA Goddard's Scientific Visualization Studio/C. Starr. (2016, September 15). *Arctic Sea Ice Annual Minimum Ties Second Lowest on Record.* Retrieved November 30, 2016, accessed at https://www.nasa.gov/feature/goddard/2016/arctic-sea-ice-annual-minimum-ties-second-lowest-on-record

20 NASA, "Arctic Sea Ice Annual Minimum Ties Second Lowest on Record." September 15, 2016. Accessed at https://www.nasa.gov/feature/goddard/2016/arctic-sea-ice-annual-minimum-ties-second-lowest-on-record

21 Page 517, F.S. Chapin III, S. F. Trainor, P. Cochran, H. Huntington, C. Markon, M. McCammon, A. D. McGuire, and M. Serreze, 2014: Ch. 22: Alaska. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 514-536. doi:10.7930/J00Z7150. Accessed at http://nca2014.globalchange.gov/report/regions/alaska

22 J. Walsh, D. Wuebbles, K. Hayhoe, J. Kossin, K. Kunkel, G. Stephens, P. Thorne, R. Vose, M. Wehner, J. Willis, D. Anderson, S. Doney, R. Feely, P. Hennon, V. Kharin, T. Knutson, F. Landerer, T. Lenton, J. Kennedy, and R. Somerville, 2014: Ch. 2: *Our Changing Climate*.
Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 19-67. doi:10.7930/J0KW5CXT.

23 Laurence C. Smith and Scott R. Stephenson. "New Trans-Arctic shipping routes navigable by midcentury." *Proceedings of the National Academy of Sciences* 110, no. 13 (2013): E1191-E1195

24 Costas Paris and Joanne Chiu. (2015, October 29). "Chinese Shipping Group Cosco Planning Regular Trans-Arctic Sailings." Wall Street Journal. Accessed at http://www.wsj.com/articles/chinese-shipper-cosco-to-schedule-regular-trans-arctic-sailings-1446133485

25 Borgerson, Scott G. "Arctic meltdown: the economic and security implications of global warming." *Foreign affairs* (2008): 63-77.

26 Scott R. Stephenson, Laurence C. Smith, Lawson W. Brigham, and John A. Agnew. "Projected 21st-century changes to Arctic marine access." Climatic Change 118, no. 3-4 (2013): 885-899.

27 Scott Stephenson, et al, "Projected 21st-century changes to Arctic marine access." Climatic Change 118, no. 3-4 (2013): 885-899.

28 U.S. Geological Survey. (2008). Circum-Arctic Resource Appraisal: Estimates of Undiscovered Oil and Gas North of the Arctic Circle. Retrieved November 21, 2016, accessed at http://pubs.usgs.gov/fs/2008/3049/

29 Scott Waldman. (2016, October 19). Arctic ice melt strains U.S.-Russia relations. Accessed October 26, 2016, at http://www.eenews.net/stories/1060044495

30 Page 7, National Research Council. Committee on National Security Implications of Climate Change for U.S. Naval Forces. "National security implications of climate change for U.S. naval forces," 2011. Retrieved from https://www.nap.edu/catalog/12914/national-security-implications-of-climate-change-for-us-naval-forces

31 Crystal Cruises. (2016, August 30). Crystal Serenity Becomes Largest Luxury Cruise Ship to Enter Fabled Northwest Passage. Retrieved November 21, 2016, accessed at http://www.businesswire.com/news/home/20160830006511/en/Crystal-Serenity-Largest-Luxury-Cruise-Ship-Enter

32 Pew Charitable Trusts. (2016, August 17). Mapping Governance Gaps on the High Seas. Retrieved November 22, 2016, accessed at http://www.pewtrusts.org/en/research-and-analysis/issue-briefs/2016/08/mapping-governance-gaps-on-the-high-seas

33 Page 3, National Intelligence Council. (2016, September 21). *Implications for US National Security of Anticipated Climate Change*. Retrieved November 21, 2016, accessed at https://www.dni.gov/files/documents/Newsroom/Reports and Pubs/Implications_for_US_National_Security_of_Anticipated_Climate_Change.pdf

34 FAO. 2016. *The State of Agricultural Commodity Markets 2015-2016*. Rome. 89 pp. http://www.fao.org/3/a-i5090e.pdf

35 Carole Dalin, Yoshihide Wada, Thomas Kastner, and Michael J. Puma. "Groundwater depletion embedded in international food trade." *Nature* 543, no. 7647 (2017): 700-704.

36 FAO. 2016. *The State of Agricultural Commodity Markets 2015-2016*. Rome. 89 pp. http://www.fao.org/3/a-i5090e.pdf.

37 Page IV, National Intelligence Council. (2012). *Global trends 2030: Alternative worlds: A publication of the National Intelligence Council*. Retrieved November 21, 2016, accessed at https://globaltrends2030.files.wordpress.com/2012/11/global-trends-2030-november2012.pdf

38 FAO. 2016. *The State of Agricultural Commodity Markets 2015-2016*. Rome. 89 pp. http://www.fao.org/3/a-i5090e.pdf

39 Keith M. Brander, "Global fish production and climate change." *Proceedings of the National Academy of Sciences* 104, no. 50 (2007): 19709-19714.

40 William Cheung, WL, Reg Watson, and Daniel Pauly. "Signature of ocean warming in global fisheries catch." *Nature* 497, no. 7449 (2013): 365-368.

41 Tim Wheeler, and Joachim Von Braun. "Climate change impacts on global food security." *Science* 341, no. 6145 (2013): 508-513.

42 Alkaly Doumbouya, Ousmane Tagbe Camara, Josephus Mamie, Jeremias Francisco Intchama, Abdoulie Jarra, Salifu Ceesay, Assane Guèye et al. "Assessing the effectiveness of Monitoring Control and Surveillance of illegal fishing: the case of West Africa." *Frontiers in Marine Science* 4 (2017): 50.

43 Andrew Jacobs, "China's Appetite Pushes Fisheries to the Brink." The New York Times, April 30, 2017. Accessed at https://www.nytimes.com/2017/04/30/world/asia/chinas-appetite-pushes-fisheries-to-the-brink.html?_r=0

44 Marcus DuBois King, "Climate Change and Vietnamese Fisheries: Opportunities for Conflict Prevention." Center for Climate and Security, Washington, DC. 2015.

45 Page 383, P.P. Wong, I.J. Losada, J.-P. Gattuso, J. Hinkel, A. Khattabi, K.L. McInnes, Y. Saito, and A. Sallenger, 2014: Coastal systems and low-lying areas. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 361-409. Accessed at http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap5_FINAL.pdf

46 FAO. 2016. *The State of Agricultural Commodity Markets 2015-2016*. Rome. 89 pp. http://www.fao.org/3/a-i5090e.pdf

47 U.S. Army Engineer Research and Development Center (ERDC). (2014). Risk Quantification for Sustaining Coastal Military Installation Assets and Mission Capabilities (RC-1701). Retrieved November 30, 2016, accessed at https://www.serdp-estcp.org/Program-Areas/Resource-Conservation-and-Resiliency/Infrastructure-Resiliency/Vulnerability-and-Impact-Assessment/RC-1701/RC-1701/(language)/eng-US, and Beeler, C. (2016, June 23). What it might take to protect the world's biggest naval base from rising seas. Retrieved November 22, 2016, accessed at http://www.pri.org/stories/2016-06-23/what-it-might-take-protect-worlds-biggest-naval-base-rising-seas

48 Constantine Samaras, "U.S. Military Basing Considerations during a Rebalance to Asia: Maintaining Capabilities under Climate Change Impacts." In, *The U.S. Asia-Pacific Rebalance, National Security and Climate Change*, C. Werrell and F. Femia (eds.), Center for Climate and Security, Washington, DC. 2015.

The Climate-Nuclear-Security Nexus: A Collision Course or a Road to New Opportunities?

Christine Parthemore[1]

Today, the international community is facing a range of nuclear challenges. New nations are pursuing civilian but dual-use nuclear capabilities. The threat of non-state actors seeking nuclear materials may be growing. Countries and international organizations are debating proper ways to enhance nuclear safety, security and nonproliferation systems to keep up with the pace of change. At the same time, governments worldwide are having difficulty managing the effects of a rapidly changing climate, such as more damaging natural disasters and resource stress. The relationships among nuclear, climate, and security risks are growing more complex and interconnected, and these issues are likely to begin converging in new ways -- possibly forming new types of geostrategic epicenters within countries, across regions, and globally.

A Confluence of Concerns

While experts have long spoken of a "nuclear renaissance" in the global energy market, a confluence of recent events related to both nuclear energy and climate change are contributing to heightened concerns about nuclear security and other security problems. The 2015 Iran nuclear agreement raised to a truly global debate the decades-old tensions between allowing peaceful nuclear energy programs to advance and preventing the expansion of nuclear threats and weapons. The International Atomic Energy Agency (IAEA) and Kazakhstan are moving forward on an international fuel bank to hold and supply low-enriched uranium for nuclear reactors, with a goal of reducing the desire of countries to invest in their own fuel enrichment capabilities.[2]The climate change negotiations concluded in Paris in December 2015 raised yet more questions about the world's nuclear trajectory.

Climate change, energy needs, regional political balancing, and other drivers have combined to push many countries to pledge increases in their nuclear energy capacity, a trend revealed by the Nationally Determined Contributions (NDCs) submitted by many countries in support of the Paris summit. How these plans are reshaped and implemented will continue to be unveiled through future climate change mitigation pledges, movements regarding nonproliferation treaties and export control mechanisms, investment decisions by individual countries and companies, and other indicators. Trends in Asia and the Middle East, where nuclear dynamics are changing the fastest and carry the starkest strategic and security consequences, are particularly important spaces to watch.

Four key trends have already emerged that animate specific security concerns. These are concerns, however, that if addressed comprehensively can create opportunities for making both climate and nuclear security policies more effective.

1. Clarity on the increasing scale of nuclear ambitions. The scale, scope, and speed of some countries' ambitions have caused perhaps the most concern by those focused on nuclear affairs. China's plans have been a major focal point as the country added public details on the extreme rate of its nuclear energy expansion efforts in late 2015. The country has announced plans to build 6 to 8 new reactors per year through 2020 and increase the rate of production thereafter, becoming the world's top nuclear energy supplier by 2030.[3] In April 2016 China publicly revealed plans to develop floating nuclear power stations to increase its electricity availability in disputed areas of the South China Sea.[4] These plans, if carried out, could be seen as enhancing the country's military capabilities in the region and contributing to already-rising tensions.

2. Detailed intentions on nuclear technologies of high concern. Less noticed are cases such as India, whose NDCs not only state the scale of its nuclear energy expansion goals but also provide details that raise deeper security questions.[5] India's NDC submission specifically notes its continuing commitment to develop fast breeder reactors -- of higher concern for their rate of plutonium production -- to illustrate the emissions mitigation technologies the country is eyeing. As the media in India reported in early December 2015, the country is planning six additional fast breeder reactors after the prototype that is currently being finished becomes operational.[6] This is particularly worrisome in light of the "presence of groups interested in and capable of illicitly acquiring nuclear materials" and other factors that recently led the Nuclear Threat Initiative to rank India as one of the countries of highest risk for theft of nuclear materials.[7]

3. Nuclear programs being pursued in absence of climate considerations. In a third category of concern are countries that appear to be reinvigorating their pursuit of nuclear energy *without* linking these ambitions to climate considerations. For the international community, this can exacerbate fears that these countries seek to develop latent nuclear weapons capabilities or challenge the existing balance of power among their neighbors. Saudi Arabia is the most extreme case, having directly tied its nuclear energy ambitions to the Iran nuclear agreement in 2015 while simultaneously omitting its nuclear energy activities from its NDC submission to the Paris negotiations.

The absence of nuclear-climate nexus thinking can be equally dangerous for domestic political and social reasons. Countries such as Jordan, Saudi Arabia, and Bangladesh are pursuing nuclear energy despite the clear indicators that the changing climate coupled with existing population and geographic constraints might limit their future ability to operate water- and land-intensive power stations. Governments pursuing nuclear power in spite of climate pressures risk driving social instability and stoking political opposition, which can raise new security risks within and beyond their borders.

4. A changing export marketplace weakening nuclear norms and standards. The emerging dominance of Russia among nuclear energy exporters is already beginning to reshape how global norms and standards of nuclear safety, security, and nonproliferation are being set. The rising international interest in expanding nuclear power generation may be on a collision course with trends of importing countries signing more extensive deals to work with suppliers with lower standards for nuclear materials tracking and less capital to invest in providing strong verification and monitoring systems. If, as planned, China becomes a prominent nuclear supplier, its actions will play a central role in setting global standards. These increasingly pervasive but little explored changes will necessitate evolution in U.S. and international nuclear security and nonproliferation policies and programs, most of which are grounded in outdated assumptions that countries such as the United States will remain the heavy-hitters in the future international market for nuclear technologies.

The international community must manage these challenges -- and others that may not yet be obvious -- if countries move forward with the nuclear aspects of their climate-change commitments and other recently announced nuclear plans.

Security and Other Risks

A number of countries are already taking steps toward establishing or expanding nuclear power programs, including Saudi Arabia, Jordan, the United Arab Emirates, South Korea, Vietnam, China, India, Bangladesh, Turkey, Belarus, Poland, Kazakhstan, and Pakistan. The countries exploring nuclear energy but not yet moving forward on concerted paths include Thailand, Indonesia, Italy, Nigeria, Kenya, Laos, Malaysia,

and Morocco.[8] Some of this growth, if it occurs, will be offset by a significant portion of the world's existing nuclear reactors aging out of the system or ending operations for financial reasons. Still, the nuclear program expansions that do take place among these and other countries in the decades ahead will carry direct and indirect security challenges that must be mitigated.

There are a number of direct safety and security risks of concern. Depending on the dominant players, the resources they are willing to commit, and other factors, nuclear norms and standards may be either weakened or strengthened in the coming decades. If global stocks of nuclear materials increase overall, this will raise concerns that recent progress in reducing the risks of diversion by terrorist organizations and other disruptive non-state actors may be slowed or set back. Of equal or greater concern is the potential for nuclear energy-consuming countries to develop their own domestic enrichment and reprocessing capabilities. Safety and security laws and regulations, human capital, operational acumen, and robust training regimens take time and sustained support to develop. A hastened rate of global nuclear expansion may make it easier for standards to be compromised as countries develop these systems. In areas of heightened risk of terrorist and other sub-national groups targeting critical infrastructure, nuclear reactors may form attractive targets.[9] This is a growing concern even in countries such as Belgium where, until recent years, that risk seemed relatively low.[10]

Indirectly, some of the countries listed above may be challenged by social disruptions or political instability if they move forward as robustly on nuclear energy as they have indicated in recent climate commitments. News reports since 2015 have shown the potential for national-level decisions regarding nuclear energy (whether for climate or other reasons) clashing with local desires.[11] Likewise, any countries advancing nuclear energy projects without sufficient consideration of the climate-related risks involved – such as water stress, power generation issues, and other resource challenges – may trigger backlash.

Foreign and security policy concerns abound as well. With increasing nuclear investments will come increasing international demand for transparency that may contribute to rising suspicions or alter threat perceptions among countries. The unending concerns that non-nuclear weapon states such as Japan and South Korea will put their peaceful nuclear capabilities to military use show how pervasive these issues can become, even when countries devote great political capital and resources to promoting non-proliferation. These concerns are perhaps highest for countries that appear to now be moving forward on nuclear power but for which these plans seem detached from their climate-related commitments or actual energy needs.

Potential Opportunities

All these risks can be managed and mitigated – in some cases, more readily than those associated with the production and consumption of other energy resources. The international community may find new opportunities in addressing the challenges outlined above.

Continuing strong international support, including financial resources, for the IAEA will have broad-spectrum benefits. The trends outlined in this brief make nuclear security and safety – and the critical global security responsibilities of the IAEA – as imperative as ever. But the agency's contributions to these global security issues extend well beyond the nuclear energy realm. IAEA leaders are increasingly touting the utility of nuclear-related technologies in mitigating and adapting to the effects of climate change, including in health, agriculture, and environmental monitoring and detection. The IAEA conducting training for detection of the Zika virus as it spread in 2016 was an example of the agency's potential future utility as the changing climate contributes to different patterns of vector-borne diseases.[12]

Next, countries, experts, and scholars should explore – not ignore or muffle – the social and political disruptions triggered by nuclear-related decisions whenever they occur. Nuclear-related protests are not new. However, the encroaching effects of a changing climate, the continually expanding access to information, legacy and emerging security dynamics, and other trends are combining in new patterns that may be changing the potency of these disruptions. Luckily, the understanding of complex crises that arise from thorny combinations of modern drivers has advanced significantly in recent years. Because of the interrelated nature of the issues, it will be key to investigate the balance of local concerns across the range of economic, security and safety, environmental, and other issues. Anti-nuclear protests may actually be about nuclear-related concerns, but they may also be predominantly driven by water stress, unemployment, injustice, and other challenges. These distinctions will be necessary to understand for designing effective remedial policies.

Finally, ensuring decision makers connect security, nuclear, climate, and other intertwined topics as they develop new policies and programs can help ensure there are complementary gains across these issue sets. For example, keeping climate and nuclear issues connected may create new diplomatic opportunities. Addressing climate change has created productive avenues of cooperation – notably, between the United States and China – that may be built upon to develop the trust and confidence required for discussions on notoriously thorny issues such as arms control. Multilateral and international mechanisms that originally focus on climate concerns may also be grown or leveraged in the future to further mitigate nuclear risks, and vice versa.[13] For the United States, any adjustments the next administration makes to the national security strategy and regional cooperative plans must thoroughly account for both the risks and opportunities that will come from whatever trajectory dual nuclear and climate trends take.

Conclusion

There exists today a decidedly worrying lack of examination of how nuclear and climate trends may shape one another in the years ahead to alter the geostrategic landscape, and how addressing these trends in tandem could both mitigate risks and create opportunities. It's imperative that conducting this kind of cross-sectoral analysis and identifying related new avenues for enhancing security happen in earnest, as both climate change-related risks and nuclear security risks are rising, and rising fast.

Notes

1 Director, Climate-Nuclear-Security Nexus Program, The Center for Climate and Security

2 Tariq Rauf, "From 'Atoms for Peace' to an IAEA Nuclear Fuel Bank," *Arms Control Today*, October 2015 Accessed at https://www.armscontrol.org/ACT/2015_10/Features/From-Atoms-for-Peace-to-an-IAEA-Nuclear-Fuel-Bank

3 Jon Stone, "China to build 40 nuclear power plants over the next five years: The Chinese state is playing a key role in the UK's nuclear power ambitions, too," *The Independent*, January 4, 2016; Tetsuya Abe, "China aims to become world's top nuclear power producer by 2030," *Nikkei Asian Review*, October 11, 2015.

4 Keith Johnson, "China's Got Nuclear Power Plans for its Fake Islands," *Foreign Policy*, April 22, 2016. Accessed at http://foreignpolicy.com/2016/04/22/chinas-got-nuclear-power-plans-for-its-fake-islands/

5 Government of India, "India's Intended Nationally Determined Contribution: Working Towards Climate Justice," 2015. Accessed at http://www4.unfccc.int/submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf

6 "India plans to construct six more fast breeder reactors," *The Economic Times-India*, December 1, 2015.

7 Nuclear Threat Initiative, "Country Profiles: India," *Nuclear Security Index*, January 2016 Accessed at http://ntiindex.org/countries/india/?index=theft

8 World Nuclear Association, "Emerging Nuclear Energy Countries," updated February 2016. Accessed at http://www.world-nuclear.org/information-library/country-profiles/others/emerging-nuclear-energy-countries.aspx

9 Turkey, which is working to develop its nuclear system for energy independence, low-emissions growth, and other objectives, is an often-cited example given domestic terrorism concerns and instability in its neighborhood. See Sinan Ülgen, ed., "Nuclear Security: A Turkish Perspective," Centre for Economics and Foreign Policy Studies, 2015. Accessed at http://edam.org.tr/en/AnaKonu/nuclear-security~-a-turkish-perspective

10 Michael D. Regan, "Brussels attacks renew concerns over global nuclear security," *PBS Newshour,* April 3, 2016. Accessed at http://www.pbs.org/newshour/rundown/brussels-attacks-renew-concerns-over-global-nuclear-security/

11 See, for example, Adrian Levy, "India's nuclear solution to global warming is generating huge domestic protests," Center for Public Integrity, December 15, 2015 Accessed at https://www.publicintegrity.org/2015/12/15/18873/indias-nuclear-solution-global-warming-generating-huge-domestic-protests

12 International Atomic Energy Agency, "IAEA Trains Experts to Use Diagnostic Tools for Quick Zika Detection," April 5, 2016. Accessed at https://www.iaea.org/newscenter/pressreleases/iaea-trains-experts-to-use-diagnostic-tools-for-quick-zika-detection; also see the agency's "Topics in Focus" highlights at https://www.iaea.org/newscenter/focus

13 A diverse group of experts developed these types of multi-decade pathways in a conversation called "The Future We Want: Is a World Without Nuclear Weapons Possible?" hosted by Reinvent on April 4, 2015. Accessed at http://reinvent.net/the-future-we-want/#scenario2

Health and Climate Security: Interconnected Security Challenges of Climate change and Infectious Disease

Kaleem Hawa[1]

Introduction: When Climate Change, Global Health, and Security Intersect

From Zika to Ebola, and from avian flu and SARS before them, security agencies, military officers, and civilian policymakers have increasingly been forced to come to grips with the impact of health and disease on national security. A key turning point for this concept – when the HIV/AIDS epidemic was deemed a national security threat by the U.N. Security Council and the U.S. National Intelligence Council[2] – has since been followed by myriad policy and defense adjustments. The White House *National Security Strategy*, the U.S. Department of Defense (DoD) *National Military Strategy*, and the *Quadrennial Defense Review* have all cited the spread of pathogens and infectious disease as a major security concern.[3] The National Security Council employs a senior director for global health security and biodefense while the DoD employs an assistant secretary of defense for health affairs[4] as well as a deputy assistant secretary of defense for health readiness policy and oversight, whose remit includes "force health protection, national disaster support, medical research and development, […] and medical readiness for 2.3 million Service members."[5]

As another emergent security concern, climate change has also been increasingly integrated into military policy and planning.[6] It is perceived by U.S. national security leadership as a threat multiplier[7] and a "direct risk to U.S. military readiness, operations and strategy."[8] Policy and governance have followed suit, urging planners to view the geopolitical and socioeconomic instability linked to extreme weather as a security threat and to improve climate preparedness and resilience.[9]

It is where these two phenomena intersect that has been most interesting to watch, with the DoD's 2014 *Climate Change Adaptation Roadmap*[10] and the Congressional submission *National Security Implications of Climate-Related Risk and Changing Climate*[11] both citing global health and pandemics as potential security risks linked to climate change. And this intersection is having real-world implications for the United States right now: Climate augmentation has led Zika and other insect-transmitted diseases to be identified as areas of concern for 2017, especially in temperate Texas, Florida, and the U.S. Gulf Coast.[12]

It is clear, therefore, that policymakers must increasingly equip themselves to understand the complex ways climate change and health intersect and the implications this will have on security. This short paper will outline some of the milieus in which the three are already interacting and how they may collide in the future.

First, climate change may alter disease trends of vector-borne illnesses in ways that directly affect the health of defense forces. Second, as climate change contributes to changing patterns of natural disasters and extreme weather events, disease transmission may be augmented. Third, climate interactions may drive conflict and refugee migratory dynamics, increasing health risks for U.S. humanitarian assistance and disaster relief personnel. Finally, serious pandemics and outbreaks hold the potential to be an existential threat, with outsized impacts on international order and, therefore, global security.

Intensifying the Risk: Climate Change, Vector-Borne Infection, and the Security Community

Promoting the health of defense forces has long been a core responsibility of the DoD and its counterparts in countries around the world. The DoD invests heavily in monitoring the health of at-home and deployed military personnel, tracks disease trends that may affect their global operations or readiness, develops medical countermeasures and diagnostics, and partners with civilian agencies to promote global health security. This is no small part of their remit either; with budget appropriations exceeding USD $579 million, the estimated global health expenditure by the DoD is larger than that of the Centers for Disease Control or National Institutes of Health in FY 2012.[13] Therefore, as the changing climate alters disease trends and conditions in a manner that influences public health, defense forces will continue to have emergent needs and interests in these developments.

One component of the DoD's health security investments that converges with climate change is vector-borne illnesses (VBIs). Transmitted by vectors such as mosquitoes, ticks, fleas, and sandflies, this class includes malaria, Dengue fever, and Zika, and accounts for more than 17% of all infectious diseases, causing more than 1 million

deaths annually.[14] The DoD has noticed – the Global Emerging Infections Surveillance and Response section of the Armed Forces Health Surveillance branch of the Military Health System partners with a variety of overseas laboratories to monitor the growth of VBIs as a threat in regions with active military deployment.[15]

To understand the VBI security risk in the context of burgeoning climate change, it is important to review the multiple factors that affect rates of transmission: the speed of vector reproduction, the frequency of vector interactions with humans, and the geospatial range of vector distribution.[16] In all three dimensions, climate disruption plays a role in intensifying the effects. Considering mosquitoes as a sample vector, evidence suggests that increases in temperature reduce extrinsic incubation periods, leading to faster mosquito maturation and proliferation[17]; in warmer climates, mosquitoes digest blood faster and feed more often, increasing transmission rates[18]; and increased precipitation patterns can expand the range of breeding sites for the mosquitoes, putting them in contact with more people.[19]

In this way, climate change becomes a force multiplier for global health risks. This is of unique concern to the DoD and other military organizations because, as a number of defense community health specialists articulated in a 2011 journal article, DoD personnel "are especially vulnerable to VBIs due to occupational contact with arthropod vectors, immunological naiveté to previously unencountered pathogens, and limited diagnostic and treatment options available in the austere and unstable environments sometimes associated with military operations."[20]

A recent case study - the Zika epidemic – helps illustrate this. Evidence suggests that climate change was a factor in the disease's proliferation – the unusually temperate 2015 El Niño likely amplified the spread of the disease,[21] while epidemiological modeling concludes that climate change had produced the most optimal conditions for mosquito-borne transmission of Zika since 1950, with higher simulated biting rates, lower mosquito mortality rates, and lower extrinsic incubation periods.[22]

The effects of this have been felt across civilian and military populations alike. As of December 2016, there were 4,809 Zika cases reported in the continental United States, and an additional 33,865 cases reported in U.S. territories like Puerto Rico.[23] Among active U.S. military personnel and their dependents, Pentagon officials have confirmed at least 41 reported cases contracted in the line of service,[24] prompting the Walter Reed Army Institute of Research (WRAIR) to describe a safe and effective Zika vaccine as an urgent global health priority.[25] Given the aforementioned connection between vector-borne illness and the climate, WRAIR and other DoD organizations that focus on infectious disease surveillance will become increasingly important in the years to come.

And it is not just mosquitoes that policymakers should be concerned with; aside from the traditional VBI transmitters, hundreds of species (eg. ubiquitous rodents, birds, and livestock) can serve as disease reservoirs, each with complex zoological interactions with the climate, and each with the possibility to cause full-scale pandemics if the mitigation and control efforts are mismanaged.

Moved into Harm's Way: Health Security in Extreme Weather Events, Natural Disasters, and International Conflict

The previous section described how climate change can increase the transmission of illnesses to military personnel, putting their health and safety at risk. But when considering the suite of military, development, and philanthropic responses typically employed by American coordinating agencies like the DoD or USAID to engage internationally, it becomes clear that climate change can intersect with health and security in additional, meaningful ways. This section will describe two major climate-connected categories of events that simultaneously (1) increase the presence of U.S. personnel in regions at high risk for disease transmission and (2) increase the likelihood of disease transmission and difficulty of treatment in these regions. They are extreme weather events/natural disasters and international conflicts/refugee crises.

Extreme weather events and natural disasters are defined by the National Centers for Environmental Information (NCEI) – formerly the National Climatic Data Center (NCDC) – as including heat waves, tornadoes, hurricanes, tropical cyclones, severe storms (tornadoes, hail, and straight-line winds), wildfires, crop freeze events, and winter storms[26] as well as what the DoD defines as "persistently recurring conditions" such as flooding and drought.[27]

Scientific evidence suggests that global warming can increase both the frequency and severity of these extreme events, with most of the evidence concentrating on heat waves,[28] precipitation and flood risks,[29] hurricane seasons,[30] and storms, tropical cyclones, and monsoons.[31] Insofar as climate change can expand and intensify the risks of these extreme events, more and more U.S. military and development personnel may be deployed in humanitarian assistance and disaster relief (HA/DR) abroad.

Climate-driven extreme events can themselves also exacerbate the underlying factors behind disease transmission, making HA/DR deployment locations more dangerous. For example, short- term increases in temperature and rainfall have been linked to accelerated parasite development that led to Plasmodium falciparum malaria epidemics and Rift Valley fever in Kenya.[33] Should the U.S. deploy humanitarian support to the region, they would have found themselves at heightened risk.

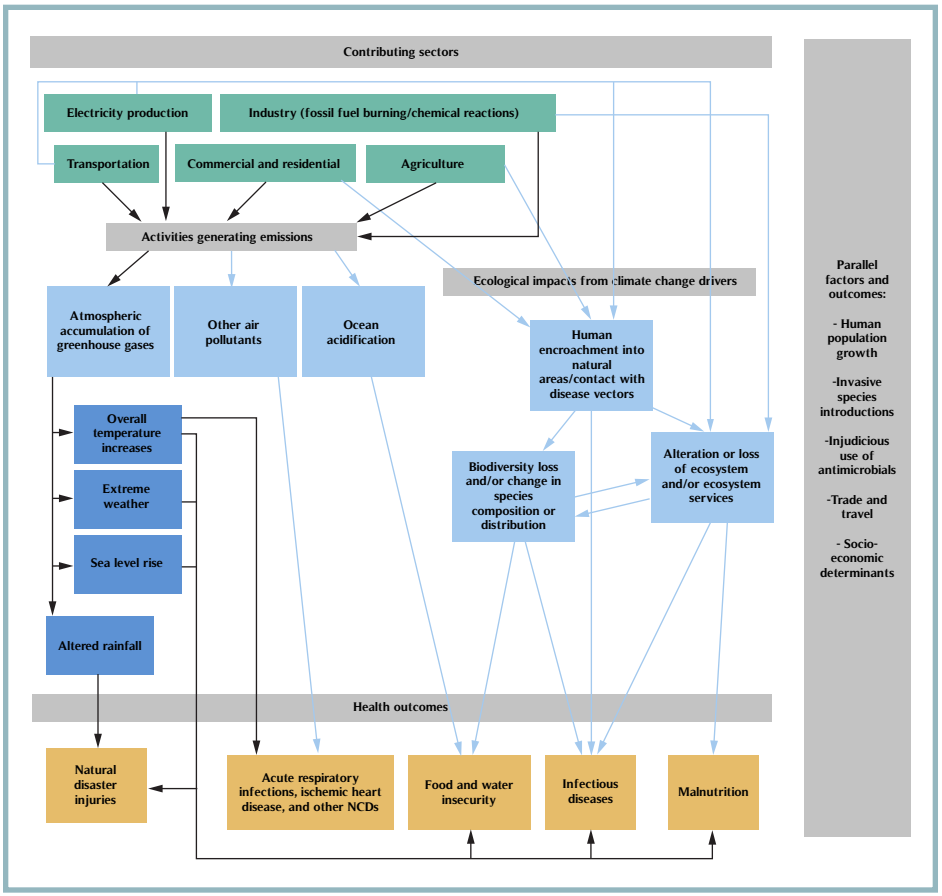


FIGURE 1: A map of how climate change can drive a variety of health risks such as infectious diseases and natural disasters through climate-driven extreme weather events, abetted by increased migration and deployment into areas with disease vectors.

SOURCE: *Climate Change and Health: Transcending Silos to Find Solutions.*[32]

These extreme events and natural disasters don't just have implications for individuals working overseas in military or aid capacities. A study in *PLoS Neglected Tropical Diseases* suggests that the Gulf Coast of the southern United States – home to a number of critical military bases and sites – is increasingly at risk of infectious diseases, in part because "periodic exposures to climate and environmental hazards, including hurricanes, floods, droughts, and oil spills" amplify risk factors such as poverty and poor sanitation.[34] Looking nationally, the NCEI estimates through its monitoring systems that the United States has experienced more than 200 such extreme events since 1980 in which overall damages were above USD $1 billion – at a total cost exceeding USD $1.1 trillion.[35] Globally, such estimates are more difficult to quantify, but are in fact both more frequent and more devastating in temperate climates with less developed infrastructure and response capacities – often the very places that most need American HA/DR responses.

Military missions have similarly been shaped by disease and climatic factors over the course of human history. Consider the spread of pandemic influenza in 1918 across U.S. military bases and army training camps in the First World War.[36] More recently, this has manifested itself in very real ways, such as the spread of Old World cutaneous leishmaniasis across areas of Syria and Iraq occupied by the Islamic State.[37]

The climate/health/security linkages are clear, and the security community has already taken notice. For instance, the U.S. *National Security Strategy* suggests that climate change has contributed to increased refugee flows and conflicts over basic resources such as food and water, thereby driving more substantial troop deployments into regions with high risk for disease transmission.[38] The World Bank reinforces this position, suggesting that climate change has significant implications for armed conflict and refugee movement given its intensification of natural disasters, deepening of resource scarcities, and effect on rising sea-levels.[39]

Moreover, these climate-assisted conflicts and migratory patterns can themselves drive outbreaks that endanger military and aid personnel. Research points to the spread of kala-azar across East Africa as a result of the conflict in South Sudan,[40] which itself has been intensified by climate change and drought according to the nation's environment minister, Deng Deng Hoc Yai.[41] It is clear, therefore, that military and aid deployments to these locations of heightened disease transmission risk present a health security challenge that policymakers will have to integrate into long-term policy and planning.

Conclusion: A Black Swan Song

There are many interconnected and overlapping chains of causality in this report. Climate change contributes to extreme weather events, natural disaster, conflict, and migration in a way that threatens the health of civilians as well as of military and HA/DR personnel. These events - as well as climate change in and of itself - also augment disease transmission in at-risk regions, particularly related to VBIs and other infectious diseases – which would be particularly worrying in an outbreak or pandemic scenario. Taken together, this is an important emerging risk trend for security and health policymakers across the world.

Though the mortality burden of such effects may be considered comparatively low (when judged against other security risks), this status quo is not assured. The *National Intelligence Council*'s Global Trends 2030 report identifies pandemic threats as the Black Swan externality with the greatest potential to disrupt the international system and cause widespread death and suffering.[42] This presents the threat posed by climate change in stark relief, given the potential for a climate-augmented pandemic as an existential international security event.

Therefore, what makes climate change and health security such an important intersection for policy analysis and investment is precisely this double potency as an amplifier: a warming climate can multiply the impact of existing threats and vulnerabilities in indigenous settings and also empower these local threats to potentially become global in nature.

Notes

1 Research Fellow, The Center for Climate and Security

2 National Intelligence Council, "The Global Infectious Disease Threat and Its Implications for the United States," January 2000, accessed at: http://www.dni.gov/nic/PDF_GIF_otherprod/infectiousdisease/infectiousdiseases.pdf

3 Kaiser Family Foundation, "The U.S. Department of Defense and Global Health," September 2012, available at https://kaiserfamilyfoundation.files.wordpress.com/2013/01/8358.pdf

4 Military Health System, "Assistant Secretary of Defense for Health Affairs," accessed at http://www.health.mil/About-MHS/ASDHA

5 Military Health System, "Deputy Assistant Secretary of Defense for Health Readiness Policy and Oversight," accessed at http://www.health.mil/About-MHS/Leadership-Biographies/David-J-Smith-MD

6 Jon Barnett, "Security and climate change," *Global Environmental Change* 13, 2003.

7 U.S. Department of Defense, "Hagel to Address 'Threat Multiplier' of Climate Change," October 13, 2014, accessed at https://www.defense.gov/News/Article/Article/603440

8 Oliver Milman, "Military experts say climate change poses 'significant risk' to security," *The Guardian*, September 14, 2016, accessed at https://www.theguardian.com/environment/2016/sep/14/military-experts-climate-change-significant-security-risk

9 U.S. Department of Defense, "DoD Directive 4715.21," January 14, 2016, accessed at http://www.dtic.mil/whs/directives/corres/pdf/471521p.pdf

10 U.S. Department of Defense, "2014 Climate Change Adaptation Roadmap," January 2014, accessed at http://www.acq.osd.mil/eie/Downloads/CCARprint_wForward_e.pdf

11 U.S. Congressional Report, "National Security Implications of Climate-Related Risks and a Changing Climate," May 2015, aaccessed at http://archive.defense.gov/pubs/150724-congressional-report-on-national-implications-of-climate-change.pdf?source=govdelivery

12 Peter Hotez, "2017 Global Infectious Diseases Threats to the United States," *PLoS Neglected Tropical Diseases,* December 22, 2016, accessed at http://blogs.plos.org/speakingofmedicine/2016/12/22/2017-global-infectious-diseases-threats-to-the-united-states/

13 Kaiser Family Foundation, "The U.S. Department of Defense and Global Health," September 2012, accessed at https://kaiserfamilyfoundation.files.wordpress.com/2013/01/8358.pdf

14 World Health Organization, "Vector-borne diseases," February 2016, accessed at http://www.who.int/mediacentre/factsheets/fs387/en/

15 Military Health System, "Global Emerging Infections Surveillance and Response System," accessed at http://www.health.mil/Military-Health-Topics/Health-Readiness/Armed-Forces-Health-Surveillance-Branch/Global-Emerging-Infections-Surveillance-and-Response

16 World Health Organization, "Climate change and human health: risks and responses," 2003, accessed at http://www.who.int/globalchange/publications/climchange.pdf

17 Leopoldo Rueda, *et al.*, "Temperature-dependent development and survival rates of Culex quinquefasciatus and Aedes aegypti," *Journal of Medical Entomology* 27, 1990.

18 Mick Gillies, "The duration of the gonotrophic cycle in Anopheles gambiae and An. funestus with a note on the efficiency of hand catching," *East African Medical Journal* 30, 1953.

19 Andrew Githeko *et al.*, "Climate change and vector-borne diseases: a regional analysis," *Bulletin of the World Health Organization* 78, 2000.

20 Mark Fukuda *et al.*, "Malaria and other vector-borne infection surveillance in the U.S. Department of Defense Armed Forces Health Surveillance Center-Global Emerging Infections Surveillance program: review of 2009 accomplishments," *BMC Public Health* 11, 2011.

21 Chelsea Harvey, "El Niño on a warming planet may have sparked the Zika epidemic, scientists report," *Washington Post*, December 19, 2016, accessed at https://www.washingtonpost.com/news/energy-environment/wp/2016/12/19/el-nino-on-a-warming-planet-may-have-sparked-the-zika-epidemic-scientists-report/?utm_term=.61788f7dbac9

22 Cyril Caminade *et al.*, "Global risk model for vector-borne transmission of Zika virus reveals the role of El Niño 2015," *Proceedings of the National Academy of Sciences* 114, 2016.

23 Centers for Disease Control and Prevention, "Zika Virus Case Counts in the US," January 4, 2017, accessed at https://www.cdc.gov/zika/geo/united-states.html

24 Barbara Starr, "41 US military members have now contracted Zika," *CNN*, August 3, 2016, accessed at http://www.cnn.com/2016/08/03/politics/zika-33-military-members-contract-disease/

25 Peter Abbink *et al.*, "Protective efficacy of multiple vaccine platforms against Zika virus challenge in rhesus monkeys," *Science* 353, 2016.

26 National Centers for Environmental Information, "Extreme Events," accessed at https://www.ncdc.noaa.gov/climate-information/extreme-events

27 U.S. Congressional Report, "National Security Implications of Climate-Related Risks and a Changing Climate," May 2015, accessed at http://archive.defense.gov/pubs/150724-congressional-report-on-national-implications-of-climate-change.pdf?source=govdelivery

28 United States Global Change Research Program, "Climate Change Impacts in the United States: The Third National Climate Assessment," 2014, accessed at http://s3.amazonaws.com/nca2014/low/NCA3_Full_Report_0a_Front_Matter_LowRes.pdf?download=1

29 Gregg Greenough *et al.*, "The potential impacts of climate variability and change on health impacts of extreme weather events in the United States." *Environmental Health Perspectives* 109, 2001.

30 Maarten Van Aalst, "The impacts of climate change on the risk of natural disasters," *Disasters* 30, 2006.

31 Earth Observatory, "The Impact of Climate Change on Natural Disasters," accessed at http://earthobservatory.nasa.gov/Features/RisingCost/rising_cost5.php

32 Catherine Machalaba *et al.*, "Climate change and health: transcending silos to find solutions," *Annals of Global Health* 81, 2015.

33 Andrew Githeko *et al.*, "Climate change and vector-borne diseases: a regional analysis," *Bulletin of the World Health Organization* 78, 2000.

34 Peter Hotez *et al.*, "The Gulf Coast: a new American underbelly of tropical diseases and poverty," *PLoS Neglected Tropical Disease* 8.5, 2014.

35 National Centers for Environmental Information, "Billion-Dollar Weather and Climate Disasters," 2016, accessed at https://www.ncdc.noaa.gov/billions/

36 Peter Wever, "Death from 1918 pandemic influenza during the First World War," *Influenza and Other Respiratory Viruses* 8.5, 2014.

37 Rebecca Du *et al.*, "Old World Cutaneous Leishmaniasis and Refugee Crises in the Middle East and North Africa," *PLoS Neglected Tropical Diseases* 10.5, 2016.

38 White House, "National Security Strategy," February 2015, accessed at https://www.whitehouse.gov/sites/default/files/docs/2015_national_security_strategy.pdf

39 World Bank Group, "Implications of Climate Change for Armed Conflict," February 25, 2008, accessed at http://siteresources.worldbank.org/INTRANETSOCIALDEVELOPMENT/Resources/SDCCWorkingPaper_Conflict.pdf

40 Waleed Al-Salem *et al.*, "A review of visceral leishmaniasis during the conflict in South Sudan and the consequences for East African countries," *Parasites & Vectors* 9.1, 2016.

41 Sophie Yeo, "Climate impacts fuelling South Sudan war says minister," *Climate Home*, May 30, 2014, accessed at http://www.climatechangenews.com/2014/05/30/climate-impacts-fuelling-south-sudan-war-says-minister/

42 National Intelligence Council, "Global Trends 2030: Alternative Worlds," 2012, accessed at https://www.dni.gov/files/documents/GlobalTrends_2030.pdf

Coastal Megacities vs. the Sea: Climate and Security in Urban Spaces

Janani Vivekananda[1] and Neil Bhatiya[2]

Introduction

Cities are on the sharp end of a range of risks from criminal violence and terrorism to demographic pressures, climate and environmental change. Coastal megacities[3] are especially at risk given the specific impacts of climate change they face, including accelerated global sea-level rise, increased storm frequency and severity, and damage to critical infrastructure such as port facilities, energy installations, and rail and road linkages, all of which are amplified as urban populations become ever larger. All these risks can lead to the loss of livelihoods as well as significant loss of life itself. Furthermore, the interaction of these risks could exceed the existing coping capacity of communities and governments, contributing to an increase in insecurity and possibly violent conflict.

The ways in which cities are particularly vulnerable or resilient to climate impacts are essential for understanding how climate risks link to political and security risks. Also essential is an understanding of the opportunities presented by cities to mitigate these risks. The nexus of risk need not hinge on a dramatic climate shock to breed security problems. The failure of service delivery, economic loss (especially unemployment) from disasters or resource security, failure to effectively manage migration, and marginalization of communities, all mean that even low-level climate change can contribute to human insecurity in megacities. Below we define the scope of the problem and how to think about workable solutions, especially with regard to governance of climate risks and migration.

Climate Change, Cities and Compound Risks

The next 50 years will see an unprecedented period of urbanization.[4] Most urbanization will occur in lower-income countries, with urban centers in South Asia, the Middle East and North Africa expected to see urban population double by 2050. In 2014, the proportion of the population living in urban areas was 39 % in lower-middle-income countries and 30 % in low-income countries. By 2050, these countries are expected to reach, on average, 57 % and 48 % urban, respectively.[5]

The IPCC's latest assessment states that climate change will have profound effects on a broad spectrum of city functions, infrastructure, and services, and will interact with and may exacerbate many existing stresses.[6] These impacts can occur both *in situ* and through long-distance connections with other cities and rural sites of resource production and extraction. Climate change could potentially contribute to violent conflicts and contribute to migration from highly vulnerable sites in cities or increasingly environmentally stressed locales. Two specific issues that characterize both urban resilience and vulnerability are the highly heterogeneous nature and the mobility of communities. This poses unique challenges to policy and governance, which need to take account of potentially weak social cohesion and governance capacity when considering any intervention. However, due to the lack of research on the issue, the IPCC qualifies this by stating that there is considerable uncertainty regarding projections.[7]

The concerns raised by the IPCC add to the growing literature exploring the political instability and complex security dynamics of urban areas, and how urban planning can, in certain contexts, contribute to instability. There has also been increased attention from the security community of the growing importance of urban areas as concentrating a host of human security challenges. For example, a recent assessment by the U.S. Army found that "megacities are rapidly becoming the epicenters of human activity on the planet and, as such, they will generate most of the friction which compels future military intervention."[8]

While the U.S. Army analysis may be overly deterministic, the compound nature of climate and security risks in cities is pertinent. It must also be stressed that the new urban agenda currently lacks specific attention to capacity-building in institutionally fragile and conflict-affected contexts where existing approaches may not be fit for that purpose. Peaceful management of the nexus of food, water, and energy in urban areas will contribute to the human and economic security goals of low- and middle-income countries. Failure to do so, conversely, will act as a net drag on productivity and could, in extreme situations, lead to political instability and civil conflict.

The Rise of Megacities: Fragility vs Resilience

The growth of megacities of course is not to be viewed simplistically as a driver of fragility. Cities can offer financial, social and cultural opportunities to their inhabitants. They can also bring economic risks and a breakdown in the traditional social and cultural behavior patterns that traditionally supported less urbanized populations.

Problems common to megacities, particularly in developing countries, include inadequate land for development, unclear land tenure rights and legislation, underdeveloped infrastructure, water shortages, poor sanitation, air pollution and traffic congestion. Coastal megacities experience these as well as other special problems related to their coastal location. These include coastal erosion, sea water intrusion to freshwater supply, loss of habitats for birds, fish and other wildlife, the depletion of fishery resources as a food supply, and public health problems related to seafood contamination. Land subsidence can occur due to construction and water extraction, and the deterioration of marine environments as an area for amenity due to marine pollution - which also poses a threat to fisheries and tourism. Natural disasters, including extreme weather, sea–level rise and its impact on critical maritime transportation infrastructure, and conflicting uses of increasingly fragile coastal areas, also pose a threat.

These challenges run headlong into a governance context where resources and expertise are already stretched. Given demographic trends of both urbanization and urban growth, these megacities are likely to come under increasing pressure, and only very few of them are equipped with the governance mechanisms to deal with the risks they are highly likely to encounter. Many of these cities will experience risks that induce fragility – thus limiting their capacity to fulfill their core functions, such as ensuring the physical security and safety of the population, maintaining infrastructure, delivering basic services such as water, sanitation and electricity, and safeguarding rights.[9] Balancing rapid economic growth, the preservation of coastal environments for sustainable development and managing relations and service provision between residents and incomers are core governance challenges facing coastal municipal authorities.

It must be noted, however, that megacities and large cities are not necessarily the most susceptible to fragility. Indeed, it is the smaller second cities that are growing most quickly and which lack the investment, institutional mechanisms and infrastructure to manage this growth. However, certain coastal megacities such as Karachi and Lagos face a particular set of risks given their pre-existing levels of fragility, meriting special attention from a security perspective.

Understanding migration

Understanding the role of migration to megacities is essential to understanding how climate risks can become political and security risks. Peaceful urban governance is difficult if large-scale urban migration isn't anticipated, planned for and managed. Of particular importance is understanding current and future patterns of migration from rural to urban areas and the reasons behind these trends in human mobility. Climate change adds another impetus for the growth of large urban areas, particularly in low-income countries. Emerging research indicates that we will see increased rural-urban movement within countries, more labor migration, and more frequent or longer-lasting circular migration patterns, particularly as the agriculture sector becomes more volatile due to projected climate impacts. With more people moving to cities, and with many cities already facing increased vulnerability to climate and disaster risks as well experiencing existing social, economic and political fragility, these dynamics will be a major determinant of urban resilience.

Climate impacts vary considerably in their potential to instigate migration. Climate change can affect migration directly or indirectly, but causality is never singular. Direct impacts, including quick-onset hazards such as flash floods and slow-onset hazards such as drought, can lead to short-term or distress migration. Indirect impacts, such as climatic shocks to markets (food, construction materials, energy supply) will have implications on people's decisions to move. Both are complex, nuanced and vary according to the particular context. Moreover, individual, community and national vulnerabilities shape responses as much as disaster effects do. Focusing on how people are vulnerable as a function of political, economic and social forces can enable a deeper understanding of post-disaster human security.

Many challenges and opportunities posed by migration into cities relate to informality. Some notable challenges exist around adequate policies to deal with undocumented migrants, how to balance the needs of urban and rural livelihood security, access to capital for poor, informal settlers, and the ways to engage non-state actors in urban governance. Informal social capital networks can also be a significant component of resilience through the social cohesion and safety nets these networks can provide.

It is unlikely that climate stresses will lead to large-scale migration, conflict or instability in megacities in the short-run, but there are already signs of increased crime and political grievances in these urban hubs that could intensify and escalate in the face of a sudden shock. As outlined above, early signs of social discontent linked to climate change are visible in Karachi and Lagos, although interwoven with economic, social, and political grievances. Whether these complaints evolve over time into scenarios more ripe for conflict or can be resolved without recourse to violence will hinge on the effectiveness of government actions to reduce vulnerability and alleviate the sense of injustice already felt by climate-affected communities. This is the case not just in megacities, but also in the regions from which people migrate.

Addressing the Governance Gap

There is a significant overlap between these global urbanization trends and a wider governmental difficulty in dealing with climate change impacts. This becomes clearer when comparing the three graphics below:

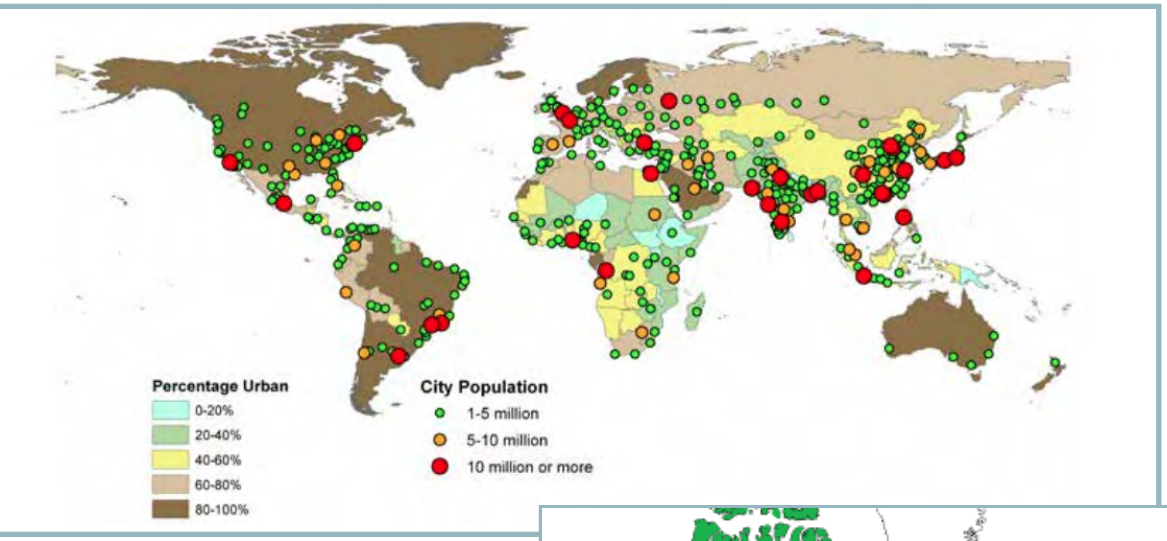


Figure 1: Global patterns of urbanization, 2015

Credit: https://www.weforum.org/agenda/2016/07/this-map-shows-the-incredible-growth-of-megacities/

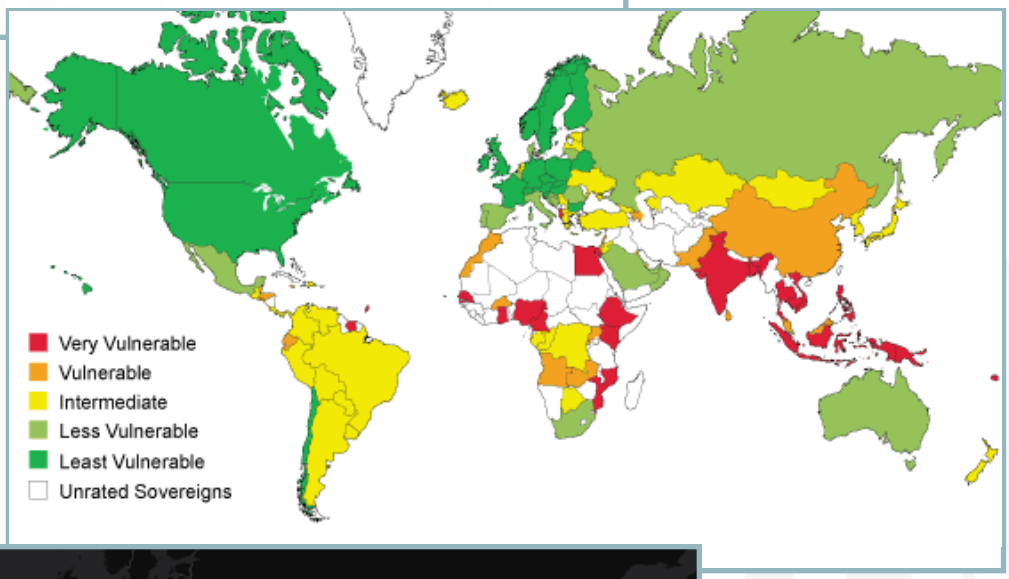


Figure 2: Potential vulnerability to climate change

Credit: Standard & Poor's 2014

Figure 3: City-level vulnerability to climate change

The first maps the growth and distribution of urban areas. The second maps the credit rating agency Standard and Poor's assessment of state-level climate vulnerability, based on three criteria (share of the population living in coastal areas below five meters of altitude; share of agriculture in national GDP[10]; and the vulnerability index compiled by Notre Dame University Global Adaptation Index [ND-GAIN], which measures the human and financial capital of national governments to adapt to climate impacts). The third penetrates more concretely to city-level measurements of vulnerability. In many cases, the three vulnerabilities overlap significantly, so that many large cities are burdened with local vulnerabilities (often because they are in conflict areas), which are compounded by national-level vulnerabilities, making any federal government response to future disaster risk sub-optimal.

Cities are not standing still in the face of these challenges. There are many examples where cities are stepping up to solve major global challenges. City leaders are forging networks within and across international boundaries to address shared problems, including climate change. However, national governments and multilateral entities such as the World Bank and United Nations are not organized to work with city-level governance mechanisms. They are still organized around servicing nation states.

Some cities have good connections to central governments and other city networks, and are thriving while others are failing to keep up with the challenge of climate change and demographic pressures. In a number of cases, the social contract binding urban authorities and citizens has unraveled. When expectations of urban residents and municipal leaders are not matched, cities become fragile. It is possible to empirically measure the extent of fragility by examining the quantity and quality of basic urban service provision and access – whether to public security, basic health, transportation or electricity.[11] And where the social contract is weakened, the risk of social unrest or conflict increases.

Conclusions and Solutions

Despite the growing importance of megacities in international security and politics, as well as the threat posed by flooding and sea-level rise, relatively little attention has been paid to the potential for environmentally induced instability in coastal megacities. Current trends, including rapid population growth, land use patterns and increasing climate impacts, suggest the costs of inaction in these urban areas are rising.

The new urban paradigm is made precarious by a nexus of population growth without land-use enforcement and basic public services, intensifying climate impacts, and divisive politics. This has the potential to undermine their aspirations to be regional economic hubs and could, over time, lead to conflict.

Regarding risk management and future urban planning in megacities, it is essential to understand the particular dynamic and risks relating to climate change. Climate change will present a profound challenge to urban areas. Facing that challenge will require resources and political will as well as innovations in governance. The present international system is built to conduct relations on a state-to-state basis. That orientation is slowly beginning to change, as new transnational approaches to climate change governance have demonstrated. But there is still a lot of distance to travel for the integration of informal as well as formal subnational governance actors as stakeholders in the international system.

There are reasons for cautious optimism: many cities have the power, the expertise and the resourcefulness to continue to take meaningful climate action. More than ever before, they are at the forefront of the issue of climate change as leaders, innovators and practitioners. However, in already fragile contexts, this dynamism and scope for engagement to address climate risks is hindered by weak capacity, lack of political will and the perception that climate change is not a priority.

In terms of practical responses, physical efforts to address climate impacts such as sea-level rise need to be coupled with attention to socio-economic factors such as social networks, livelihoods and efforts to enhance governance. It is also critical to ensure support for rural as well as urban informal livelihoods. Rural areas are where many of the most vulnerable earn their living and where economic stress and the push to migrate to urban centers is first felt. Any strategy must ultimately encompass grievances such as inequality, marginalisation and the disenfranchisement of youth – especially men.

But to ensure that policy responses genuinely address the complex risks posed to megacities by climate change, we urgently need a better understanding the links between migration, urban resilience, climate change and fragility. This issue is a major lacuna within the research community and, as such, is largely overlooked in policy and programing. While there is increased focus on the perceived negative implications of migration on national security, the relationship between climate change, migration, cities and conflict needs to be understood if attempts to promote sustainable urban development are to build resilience to climate change and conflict in an increasingly mobile and urban world.

Notes

1 Senior Advisor on Climate Change and Peacebuilding, adelphi;

2 Climate and Diplomacy Fellow, The Center for Climate and Security.

3 A megacity is defined by the UN as a city with a population over ten million people

4 United Nations Population Division, World Urbanization Prospects (2014 Revision), https://esa.un.org/unpd/wup/, accessed November 14, 2016.

5 Ibid.

6 Revi, A., D.E. Satterthwaite, F. Aragón-Durand, J. Corfee-Morlot, R.B.R. Kiunsi, M. Pelling, D.C. Roberts, and W. Solecki, 2014: Urban areas. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press (New York, 2016), accessed September 21, 2016, 556.

7 Nevertheless, those concerned with international security should not wait for the absolute certainty of projections to be confirmed before adopting policies needed to mitigate those impacts. If climate change even has a ten percent chance of making living in a city more expensive and more dangerous, then it is worth investing time and capital in preventing it.

8 Chief of Staff of the Army, Strategic Studies Group, Megacities Concept Team, "Megacities and the United States Army
Preparing for a Complex and Uncertain Future", accessed September 21, 2016.

9 Conceptualising City Fragility and Resilience, de Boer et al, UNU Centre for Policy Research, Working Paper 5, 2016

10 Standard and Poor's 2014 https://www.globalcreditportal.com/ratingsdirect/renderArticle.do?articleId=1318252&SctArtId=236925&from=CM&nsl_code=LIME&sourceObjectId=8606813&sourceRevId=1&fee_ind=N&exp_date=20240514-20:34:43

11 Conceptualising City Fragility and Resilience, de Boer et al, UNU Centre for Policy Research, Working Paper 5, 2016

The Weaponization of Water in a Changing Climate

Marcus D. King[1] and Julia Burnell [2,3]

Water stress across the Middle East and Africa is providing an opportunity for subnational extremist organizations waging internal conflict to wield water as a weapon. The weaponization of water also drives conflict that transcends national borders, creating international ripple effects that contribute to a changing geostrategic landscape.

Climate change-driven water stress in arid and semi-arid countries is a growing trend. This stress includes inadequacies in water supply, quality, and accessibility.[4] These countries are consistently experiencing chronically dry climates and unpredictable, yet prevalent, droughts. Predicted future climate impacts include higher temperatures, longer dry seasons, and increased variability in precipitation. In the coming decades, these factors will continue to stress water resources in most arid regions.[5]

It is accepted wisdom that parties generally cooperate over scarce water resources at both the international and subnational levels, with a very few notable exceptions that have resulted in internal, low-intensity conflict.[6] However, tensions have always existed: the word rivalry comes from the Latin word *rivalus*, meaning he who shares a river.[7] Rivalry is growing at the sub-state level, leading to intractable conflicts. Social scientists have long observed a correlation between environmental scarcity and subnational conflict that is persistent and diffuse.[8] Disputes over limited natural resources have played at least some role in 40 percent of all intrastate conflicts in the last 60 years.[9]

Recent scholarly literature and intelligence forecasts have also raised doubts that water stress will continue to engender more cooperation than conflict. For example, a key U.S. Department of Defense planning document argues "future water supply challenges could affect food production, and cause resource competition … that will aggravate existing stressors such as social tensions – conditions that enable terrorism and other forms of violence."[10]

Stressors in the form of ethnic divisions feature prominently in the conflicts in arid zones that we analyzed, including Syria/Iraq, Somalia, and Nigeria. A new study finds that coincidence of weather variations (such as droughts) and war is dramatically higher in countries with inter-ethnic social tensions. These divisions play a greater role than poverty, income inequality, or even past propensity for conflict.[11]

Pathways of influence linking water stress and conflict in fragile Middle Eastern and North African states are becoming more visible and carry worldwide implications for states with similar characteristics. These paths are extending beyond borders, facilitating the spread of violent extremism, disrupting energy markets, and deepening human suffering.

Water as a Weapon

The U.S. intelligence community suggests that as water becomes scarcer, states may begin employing water as an interstate "weapon," even in areas where cooperative solutions had prevailed.[12] Our research finds that extremists groups are already using water as a weapon at the subnational level.

In its most basic form, a weapon is "a *means* of gaining advantage or *defending* oneself in a conflict or contest."[13] Wielded by a group, it can take the form of an item, action, or offensive capability used or intended to kill, injure, or coerce. We observed the use of water as a weapon by sub-state militants across a spectrum of conflict in selected countries. We classified weaponization incidents by the intentions of the perpetrator as follows:

- **Strategic Weaponization:** The use of water 1.) For virtual or actual control or destruction of large or important areas, populations or infrastructure. or. 2.) As an asset to fund state-like activities such as territorial administration or major weapons acquisition.

- **Tactical Weaponization:** generally, the use of water against targets of strictly military value. Weaponization of water on a small, local scale was generally characterized as tactical.

- **Coercive Weaponization:** use of water as an instrument of subjugation through the creation of fear among non-combatants of water supply disruption or contamination.

Ironically, the earliest historical records of water weaponization are among the ancient Kingdoms of Mesopotamia, a region that constitutes the modern Syrian and Iraqi battlefield.[14] Indeed, the conflict in Syria and Iraq paints the most vivid picture of subnational actors' use of the water weapon. Our extensive research shows that Islamic State (IS) was responsible for 21 of the 44 weaponization incidents we catalogued rom 2012-2015. The al-Nusrah Front, an al-Qaeda affiliate, was responsible for three.[15]

Strategic Weaponization of Water

Islamic State's systematic and sustained deployment of the water weapon is unprecedented in modern conflict.[16] However, IS's sudden strategic seizure of the Mosul and Haditha dams has received attention from concerned parties.

On August 7, 2014, IS seized control of the 3.2-kilometer-long Mosul dam on the Tigris River upstream of the cities of Mosul and Baghdad in northern Iraq. IS's action and the corresponding threat of intentional sabotage that could kills thousands and inundate Baghdad with a wall of water was a factor in prompting the U.S. to launch an aerial bombing campaign.[17] From August 17-18, Iraqi and Kurdish forces fought a pitched battle that reclaimed the dam with the support of about 35 U.S. airstrikes.[18]

Tactical Weaponization of Water

Islamic State has also successfully wielded the water weapon at the tactical level. In 2014, IS militants intentionally diverted water from nearby rivers in the Shirwain area of the Iraqi Diyala Province. This action halted the advance of Iraqi security forces on at least two occasions. In what we call *unintentional weaponization*, the collateral damage included the flooding of nine villages and displacement of the resident populations.[19]

A feedback loop is discernible in Diyala and other locations where water weaponization's impact on infrastructure created desperate conditions and impetus for more conflict. The prospects of recovery remain dim. As of December 2015, 35% of Syria's treatment facilities were damaged by various combatants.[20]

Coercive Weaponization

Like Syria, Somalia was hit by regional droughts in 2011. It was at this time that Somali government military forces made inroads against the Islamist extremist group al-Shabaab in the ongoing civil war, eventually retaking most major cities. As a response, Al-Shabaab changed its traditional guerilla tactics and started to cut off liberated cities from their water sources so that they could demonstrate at least some kind of power and presence. Climate change, lack of food and continued conflict involving water

weaponization took an enormous social toll.[21] Limited access of humanitarian agencies exacerbated by al-Shabaab's actions led to more than a quarter million deaths and hundreds of thousands of displaced persons.[22] Al-Shabaab's attempt to gain legitimacy and subjugate the population was ultimately unsuccessful for many reasons. However, deployment of the water weapon left enormous misery in its wake.

Water as an Accelerator of Violence

In other cases water is both a means and objective of war. A protracted conflict currently pits members of the semi-nomadic Muslim Fulani tribe against predominantly Christian farmers in Nigeria's Middle Belt, an ecologically diverse but increasing arid transition zone between the relatively temperate Niger River Delta and the arid northeast. The primary conflict driver is contested access to increasingly degraded grazing lands.[23]

The roots of the conflict stem from the overlap of the Middle Belt's most productive agricultural lands with the traditional migration route of the Muslim Hausa-Fulani herdsmen, a large ethnic group spread across northern Nigeria and neighboring states.[24] Their annual search for grazing lands for their cattle encroaches farmlands plagued by drought. The food security of farmers, including members of the Christian Yoruba tribe, is increasingly jeopardized.[25]

When cattle consume or trample crops, retaliation may involve killing of livestock or direct poisoning of water sources. Hausa-Fulani herders sometimes attempt to settle. However, they face a system of land tenure and inheritance rights that give special recognition and social services to generational landowners.[26] These dynamics, combined with mutual dissatisfaction caused by sparse economic opportunities, has created a conflict spiral with no end in sight.

The conflict in the Middle Belt is little understood and has not received widespread media attention. The 2015 Global Terrorism Index reported that "Fulani militants" alone were the fourth most deadly terrorist group in the world, responsible for the deaths of 1,229 people in 2014.[27] In 2016, herdsman killed more Nigerians than Boko Haram, the extremist group widely considered the primary threat to Nigerian security.[28] However, there is a concerning linkage. Sources within the Nigerian military allege that Boko Haram members are infiltrating Fulani communities in response to battlefield setbacks.[29]

Poor national policies contribute to deteriorating conditions. Nigerian authorities' attempts to manage the conflict have been ineffective, and local authorities have depicted pastoralists as the sole aggressors.[30] Inability to prevent conflict also creates an unstable environment for effective water management policy.

Global Ripple Effects

Internal conflicts in the drought-afflicted countries described herein will have wider geopolitical, economic and security impacts:

People displaced across borders by drought or conflict present myriad challenges. Some migrants flee one politically fragile state only to land in another equally precarious situation. Somali refugees who make the dangerous crossing of the Arabian Sea to Yemen are an example.[31] Migrants from all three nations we surveyed are seeking refuge in Europe in large numbers, placing strain on social support and political systems.

In Syria and Iraq, it appears that the military coalition formed against IS will be victorious in its ground operations. But even as the Islamic State is dismantled, the area is a persistent epicenter of global jihad. IS-inspired terrorist attacks are pervasive in Europe.

Compounding challenges emerge from the war in Somalia, including large-scale humanitarian commitments, displacement across borders, and internationalization of the conflict to neighboring states.[32] Somalia sits on the Bab-el-Mandeb Straits, a vulnerable touch point between the continent of Africa and the Middle East. Piracy has been rampant in the strategic route for Persian Gulf oil, natural gas, and petroleum product shipments to Europe and North America, and European and North African oil exports to Asia.[33]

Nigeria is an important rising power due to its sizable population, oil production and military posture. Supply disruptions for Nigeria and, to a lesser extent, Iraq have created uncertainty in the global oil market. Nigeria is also a strategic U.S. partner, providing a bulwark against extremism through support of regional peacekeeping missions. Even as Nigeria struggles to manage multiple internal conflicts, al Qaeda in the Islamic Maghreb (AQIM) has already gained influence in neighboring countries, and linkages with Boko Haram have been established.[34]

Perhaps the greatest concern is the growing linkage between extremist organizations. A network among the major extremist groups discussed in this article is now discernible. For example, there are accusations that the Fulani militants have been infiltrated by Boko Haram.[35] Boko Haram fighters have conducted training in Somalia with al-Shabaab.[36] Although their strongest ties are with al-Qaeda, a faction of al-Shabaab has declared allegiance to IS.[37, 38]

Conclusion

A changing climate stresses water resources and increases state fragility in arid countries. Water stress and poor water governance were factors that enabled extremist groups' exploitation of the water weapon. Localized conflict is increasingly likely to scale up to higher order security risks as extremists metastasize and coordinate.

Water weaponization is a tool that will only swell vulnerable populations and create lasting damage unless swift and decisive policy measures are taken. Better coordination between the global community and national level actors is essential in countries where deteriorating ecological and social conditions are creating growing instability.

Notes

1 John O. Rankin Associate Professor of International Affairs; Director, M.A. Program in International Affairs, Elliott School of International Affairs, George Washington University

2 Elliott School of International Affairs, George Washington University

3 This essay draws on the results of a research project undertaken through the Climate and Water Security Initiative at the Elliott School of International Affairs.

4 Peter Schulte, "Defining Water Scarcity, Water Stress, and Water Risk: It's Not Just Semantics," *Pacific Institute Insights,* February 4, 2014. Accessed at http://pacinst.org/water-definitions.

5 United Nations Economic and Social Commission for Western Asia (UN ESCWA), "Climate Prediction and Extreme Climate Indices for the Arab Region," 2015.

6 Oregon State University's Transboundary Freshwater Dispute Database (TFDD), 2016, accessed at http://www.transboundarywaters.orst.edu/database/.

7 Kramer A.T. Wolf and A. Carius and G.D Dabelko, "Managing Water Conflict and Cooperation in Worldwatch Institute," in *State of the World 2005*, (New York: Norton & Company, Inc, 2005). Pp 80-99.

8 Thomas F. Homer-Dixon, *Environment, Scarcity, and Violence*, (Princeton: University Press, 1999), 13.

9 Aaron Sayne, "Climate Change Adaptation and Conflict in Nigeria," United States Institute of Peace, 2012. Accessed at https://www.usip.org/sites/default/files/Climate_Change_Nigeria.pdf

10 United States Department of Defense (US DoD), *Quadrennial Defense Review 2014*.

11 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*, 9216 (2016), doi:10.1073/pnas.1601611113.

12 Office of the Director of National Intelligence, *Intelligence Community Assessment: Global Water Security*. 2012.

13 Oxford Dictionary

14 Pacific Institute Water Conflict Chronology, 2013. Available at http://www2.worldwater.org/conflict/list.

15 Marcus King, "The Weaponization of Water in Syria and Iraq" *Washington Quarterly*, Volume 38., Number 4, Winter 2016: 153-169.

16 Ibid.

17 "Obama applauds Recapture of the Mosul Dam, Says Iraq Must Unite because ' the Wolf's at the Door,"' *The Associated Press*, last modified August 8, 2014. Accessed at http://www.theglobeandmail.com/news/world/latest-round-of-us-airstrikes-aimed-at-helping-iraqis-reclaim-mosul-dams/article20091967/.

18 Vivian Salama and Diaa Hadid, "Obama: Iraq forces retake Mosul Dam from militants" *Associated Press*, August 18, 2014.

19 Erin Cunningham, "Islamic State jihadists are using water as a weapon in Iraq," *The Washington Post*, October 7, 2014, accessed, April 25,2017. Accessed at https://www.washingtonpost.com/world/middle_east/islamic-state-jihadists-are-using-water-as-a-weapon-in-iraq/2014/10/06/aead6792-79ec-4c7c-8f2f-fd7b95765d09_story.html.

20 Oxfam "Syria in Crisis," last modified December 5, 2014, accessed April 30, 2017. Accessed at http://www.oxfam.org.hk/en/news_2623.aspx.

21 "Al-Shabaab's 'water terrorism' is yielding results and tragedy in Somalia's civil war" PRI, August 2014. Accessed at https://www.pri.org/stories/2014-08-08/how-al-shabaab-using-water-tool-terrorism

22 International Organization of Migration (IOM), "Dimensions of Crisis on Migration in Somalia: Working Paper February 2014," Department of Operations and Emergencies, 2014.

23 Peter Akpodiogaga-a Ovuyovwiroye Odjugo. "General Overview of Climate Change Impacts in Nigeria." *Journal of Human Ecology* 29, no. 1 (2010): 47-55.

24 Chika Oduah, "Nigeria: Deadly Nomad-Versus Farmer Conflict Escalates," *Al Jazeera*, July 6, 2016. Accessed at http://www.aljazeera.com/news/2016/07/nigeria-deadly-nomad-farmer-conflict-escalates-160704043119561.html

25 Okoli Al Chukwuma and Atelhe George Atelhe, "Nomads Against Natives," *American International Journal of Contemporary Research,* Vol. 4 No. 2; February 2014: 82.

26 Aaron Sayne, "Rethinking Nigeria's Indigene-Settler Conflicts," United States Institute of Peace, 2012. Accessed at https://www.usip.org/sites/default/files/SR311.pdf

27 "Nigeria: Investigate Massacre, Step Up Patrols-Hundreds Killed by Mobs in Villages in Central Nigeria," *Human Rights Watch*, March 8, 2010. Accessed at https://www.hrw.org/news/2010/03/08/nigeria-investigate-massacre-step-patrols

28 Council on Foreign Relations Nigeria Security Tracker, 2012, available at http://www.cfr.org/nigeria/nigeria-security-tracker/p29483

29 Chika Oduah, "Nigeria: Deadly Nomad-Versus Farmer Conflict Escalates," *Al Jazeera*, July 6, 2016. Accessed at http://www.aljazeera.com/news/2016/07/nigeria-deadly-nomad-farmer-conflict-escalates-160704043119561.html

30 Aaron Sayne, "Rethinking Nigeria's Indigene-Settler Conflicts," United States Institute of Peace, 2012. Accessed at https://www.usip.org/sites/default/files/SR311.pdf

31 International Organization of Migration (IOM) and SciencesPO IDDRI, "The State of Environmental Migration 2011: Drought in Somalia, a Migration Crisis" Institut du Developpement Durable et des Relations Internationales, 2012.

32 International Organization of Migration (IOM) and SciencesPO IDDRI, "The State of Environmental Migration 2011: Drought in Somalia, a Migration Crisis" Institut du Developpement Durable et des Relations Internationales, 2012.

33 "Oil trade off Yemen coast grew by 20% to 4.7 million barrels per day in 2014," *U.S. Energy Information Administration*, 2015. Accessed at https://www.eia.gov/todayinenergy/detail.php?id=20932

34 "Boko Haram too extreme for 'al Qaeda in West Africa' brand" *Reuters,* May 28, 2014. Accessed at http://www.reuters.com/article/us-nigeria-bokoharam-analysis-idUSKBN0E81D320140528

35 Chika Oduah. "Nigeria: Deadly Nomad-Versus-Farmer Conflict Escalates," *Al Jazeera*, July 6, 2016. Accessed at http://www.aljazeera.com/news/2016/07/nigeria-deadly-nomad-farmer-conflict-escalates-160704043119561.html.

36 "Nigerian Boko Haram fighters trained in Somalia: president," *Reuters*, February 14, 2016. Accessed at http://www.reuters.com/article/us-somalia-boko-haram-idUSKCN0VN0MF

37 Mapping Militant Organizations, Stanford University, 2017, Accessed at http://web.stanford.edu/group/mappingmilitants/cgi-bin/groups/view/61

38 Tomi Oladipo "Al-Shabab wants IS to back off in East Africa," BBC, 24 November 2015, Accessed at http://www.bbc.com/news/world-africa-34868114

Signal, Noise and Swans in The Arctic

David Titley[1] and Katarzyna Zysk[2]

The Arctic is a unique maritime domain and physical environment that is changing faster than any other place on Earth. The trend of abrupt and substantial variations in ice coverage, increasing temperatures, waves and coastal erosion, and unusual weather patterns is likely to continue, given persistent emission of greenhouse gases, primarily by the world's industrialized countries. These transformations profoundly affect both weather and climate in much of the Northern Hemisphere, and spur political dynamics that force governments and organizations to form new policies toward the Arctic region. Changes in energy and commodity prices, global transportation infrastructure, environmental and governance policies, as well as Russia's relations with the outside world, all impact the trajectory and pace of Arctic development.

This article examines the "signals" (ongoing trends), the "noise" (short-term fluctuations) and the "swans" (the wild cards) in the environmental changes in the Arctic and their geopolitical implications. Considering the rate and scope of the multilayered regional transformations, this paper argues that it is best to focus on the signals and not the noise, or the short-term fluctuations, while hedging, to the best of our ability, against the swans.

The Arctic is changing faster than any other place on Earth. The collapse of ice coverage and thickness, increasing temperatures, waves and coastal erosion, and changing Arctic weather patterns are not only unprecedented in human civilization, but also likely to continue, given the persistent emission of greenhouse gases. These physical changes profoundly affect both weather and climate in much of the Northern Hemisphere, and spur political dynamics that increasingly link the Arctic to world affairs.

The signal and the noise: Persistent trends vs. short-term fluctuations

Environmental change

The most dramatic change in Arctic conditions over the past 30 years is the decrease in both coverage and thickness of the summer sea ice. The change in sea ice impacts virtually every other component of the Arctic, both natural and human ecosystems, transportation, exploration, hunting and subsistence, and potentially even the weather in much of the Northern Hemisphere.[3]

While there is much year-to-year variability in the amount of ice loss, the decadal signal is relatively constant, and shows a loss of 80,000 to 90,000 km2 -- the size of South Carolina -- each year.[4] Much of this loss occurs in the late summer and early fall. While Arctic sea ice is decreasing in the winter at a rate of 2.6 percent per decade, the summer sea ice is decreasing at a much greater rate of 13.3 percent per decade.

Equally important, long-term trends show the thickness of Arctic sea ice is thinning, a consequence of warmer air and ocean temperatures, and the thick multi-year ice is flowing into the Atlantic Ocean through the Fram Strait, the deepest gateway to the Arctic Ocean. Although reliable and sustained observations of ice-thickness are difficult to acquire, estimates based on submarine data show Arctic sea ice to be 33 to 50 percent thinner now than in the 1950s.

Determining the long-term trend signal from the year-to-year noise is particularly challenging. The Arctic is undergoing changes not previously observed by human civilization so there is little historical knowledge to draw upon. Until recently, many computer projections underestimated significantly the rate at which the Arctic was losing summertime ice. However, as observed in 2013 and 2014, the rate of the decrease is not linear and there will continue to be seasons where summer ice coverage increases for a few years.

While some of the most aggressive forecasts of an ice-free Arctic later this decade (i.e., Maslowski's assessments[5]), most projections are for a month of nearly ice-free conditions to occur prior to 2050.[6] However, even with that relatively conservative projection, it is still likely that the Arctic could experience a few days or weeks of virtually ice-free conditions years or even decades earlier. While the substantive impact of that event may be limited, it may be another political wake-up call in the Arctic, similar to the impact of Russia's policies in 2007–2008, symbolically expressed by the illustrious planting of the Russian flag under the North Pole in 2007. The event, although broadly overstated, was accompanied by such dynamics as an increase in Russian military activity, anti-Western rhetoric, the slump in US/NATO–Russia relations, and the 2008 war in Georgia. The Russian policies and their perceptions outside have been major factors – along with the climatic deviations and Arctic energy euphoria -- that have caused other countries to take notice of the Arctic dynamics.

Economic development

While the environmental changes may be rapid, the economic development is proceeding at a slower pace. Although the ice is decreasing, its amount in any given location at a specific point in time is still subject to great uncertainty. This variability, along with other external influences such as commodity prices, regulations and policies, relative economic opportunities in non-Arctic regions, and, in the case of Russia, international sanctions, economic crisis and long-standing structural problems, all modulate the rate of expansion of human activity in the Arctic.

One example is the rate of growth of the Northern Sea Route (NSR), the shipping route extending from Europe across the top of Russia, exiting through the Bering Strait to the Pacific Ocean. Before 2010, the NSR functioned traditionally as a Russian domestic transport passage. However, after a significant slowdown in the 1990s, the NSR experienced rapid growth through 2013 with 71 vessels making the NSR transit, accounting for approximately 1.36 million tons of cargo.[7] The number of transits decreased, however, to just 31 in 2014.[8] Thicker ice, lower commodity prices, political tensions and sanctions had a cumulative chilling effect. While the signal is for growth of the NSR, it is not at the exponential rates the noise suggested between 2008 and 2013.

Tourist traffic on cruise ships is evolving in a similar manner. While tourism in Svalbard, Greenland and Canada has slowly grown over the past decade[9], the growth has been variable, or noisy, both from year to year and within each region.

These large fluctuations make policy decisions much more challenging. While no nation or organization wants to be too late to react to changes in the Arctic, investing time and resources ahead of the true need is also not wise.

The Swans: Wild-cards

Nassim Nicholas Taleb defined the concept of "black swans" as events that are rare, have high impact, and are predictable only in retrospect.[10] Taleb also discusses "grey swans," or improbable and significant events that are on the edge of predictability. Given that the physical changes occurring today in the Arctic are beyond modern human experience, the Arctic has high potential for either type of "swan" events, as traditional risk and probability theories based on normal distributions may not apply. While we do not pretend to have predictive powers, it is helpful to think through scenarios that could happen and imagine their impact on a future Arctic. The following scenarios are simply examples of some events that, if they were to happen, could fundamentally change how the world views the Arctic.

Shipping and Oil Spill Disasters

While cruise ship and oil spill disasters are discussed frequently, there has been little written about the higher-order consequences beyond the immediate tragedy. In 2014, nearly 65 percent of cargo shipped along the Northern Sea Route was oil-based product.[11] What are the long-term impacts of a ship grounding or collision at the eastern or western edges of the NSR, sending oil into the territorial waters of other nations? Or the ramifications of a large cruise ship that hits a rock, ice, or catches fire in the Arctic, resulting in hundreds or thousands of deaths, exposing the lack of rescue capacity despite the Arctic Council's 2011 Search and Rescue (SAR) Agreement? What if most of those fatalities are citizens of a country not a full member of the Arctic Council?

Apart from potential disastrous environmental consequences, an oil spill in the Arctic is likely to impede the economic development in the region as well as threaten the way of life of the indigenous population. The long response time in the Arctic makes it necessary to reach a decision as quickly as possible, potentially made harder when the accident or its consequences encompass several state and non-state stakeholders.

A different type of shipping disaster would be a large cruise accident in the Arctic. As the sinking of the *Costa Concordia* demonstrated, human error and blunders on the ocean have not been eliminated by modern technology. Dozens of passengers died from an accident within sight of the Italian mainland. A similar accident in the remote reaches of Greenland or the Canadian Arctic is likely to have a far-higher death toll and would expose the inadequate SAR and law enforcement capacity in the region.

In addition to the tragedy of severe and sustained environmental damage or numerous fatalities, it is an open question how the geopolitical repercussions would unfold. Such an event could bring nations closer together to work in cooperation to prevent such future tragedies. The sinking of the *Titanic* in 1912 spurred the adoption in 1914 of the first international convention for the Safety of Life at Sea (SOLAS). Or, conversely, would another nation use the events as a pretext to fundamentally disrupt the Arctic Council and force a change in Arctic governance?

Greenland's Future

Another potential scenario considered in recent years is that Greenland "goes alone" by seeking independence and is aggressively courted by China. How might that alter the dynamics among Arctic nations and between Arctic and non-Arctic states? While the collapse in the oil markets in 2014 and a general slowdown in the economic viability of Arctic-related projects have dampened these tendencies, commodity prices will rebound at some future time. Have Europe and the United States fully thought through the consequences of an independent Greenland with about 50,000 citizens sitting astride a strategic strait to the Arctic and halfway between Europe and North America?

Strange Bedfellows

Although unlikely today, it is possible that either the United States or Canada could force a resolution to the Northwest Passage (NWP) sovereignty issue at some point in the future. Canada claims the NWP as "internal waters," while the United States and other nations state the maritime channel is an "international strait" as defined under the UNCLOS. Currently there is almost no routine shipping through the NWP, and Canada and the U.S. agree to disagree about the strait's ultimate status. If the United States or Canada decided to force a resolution to the NWP sovereignty issue, would Russia and China side with Canada? Russia already defines the NSR as an integrated national transport route, and China might use the Canadian NWP precedent to bolster its own claims on control of the South China Sea. What would that support for China look like? Would there be pressure (asymmetric response) applied in other parts of the world? Could the dispute be enough to rupture the North American Free Trade Agreement (NAFTA) and realign trading blocks later this century?

The Russia Factor

Uncertainty connected to Russia's domestic, foreign, and security policies and their impact on the Arctic is a recurring theme in circumpolar relations. While the Russian authorities have officially assured that they do not see any immediate threats in the Arctic, their anxieties and fears concern several regional issues. Commander in Chief of the Russian Navy, Admiral Viktor Chirkov, stated in March 2014 that the Arctic polar region could be potentially used to create new security threats against the whole Russian territory, which, he said, justifies the military modernization of both nuclear and conventional deterrence.[12] Since Putin's return as president in May 2012, Russia has embarked on a large-scale military build-up in the region including all defense branches. One scenario is that sanctions against Russia continue, the military situation in Ukraine deteriorates and virtually all communication ceases between the West and Russia. Russia declares its entire Exclusive Economic Zone in the Arctic to be a security zone and requires permission for any vessel to sail in or through. Despite volatile commodity prices and economic recession, Russia has successfully completed upgrading its Arctic military capabilities and training to modern standards. How will the West respond? Would the Western countries unilaterally cede military superiority to Russia in the Arctic, or would the Arctic again become a contested operating theatre?

Conclusions

While the Arctic continues to change rapidly, that change will not be uniform in its rate or impact. The ever-increasing concentrations of greenhouse gasses in the atmosphere will continue to force changes in Arctic weather patterns and ice conditions for decades to come. However, economic development, trade routes, commodity prices, environmental and safety regulations, and geopolitical events that happen thousands of kilometers away from the Arctic will all impact the rate and scale of the regional development, which will not be

linear. One consequence of the variations in the political interest, and related investment and preparedness, in the Arctic may be a higher risk for accidents in the region, which will still continue becoming more accessible, even without an energy or transportation bonanza. Another risk is a greater danger of miscalculation. If we ignore the region and then are confronted with a sudden crisis, how much expertise and understanding will there be to best manage that (potential) future crisis?

These factors complicate policy options and actions, as governments do not want to be too late in a reactive mode nor too early by spending finite resources when they are not yet needed.

The best course of action is to consciously identify and separate out the long-term signals from the shorter-term noise while continually thinking through potential swan scenarios and how best to manage and minimize those risks.

For the United States, as for the other Arctic nations, now is the time to invest in long-term, foundational capabilities that will be required as the Arctic opens up. In addition to mapping, better weather, ocean and ice forecasting, and infrastructure capabilities, U.S. government agencies and the private sector should gain experience operating in the Arctic, a region that is still harsh and without much organic support capabilities. How best to partner with, learn from, and respect the native cultures that have lived in the Arctic for thousands of years must also be a component of any Arctic plan.

Notes

1 Professor of Practice, Department of Meteorology, Director, Center for Solutions to Weather and Climate Risk, Professor, School of International Affairs, Penn State University

2 Associate Professor at the Norwegian Defence University College (NDUC)/Norwegian Institute for Defence Studies in Oslo

3 Jennifer A. Francis, and Stephen J. Vavrus. "Evidence linking Arctic amplification to extreme weather in mid-latitudes," *Geophysical Research Letters* 39, no. 6 (2012).

4 *SOTC: Sea Ice, National Snow and Ice Data Center*, January 8, 2015, accessed at https://nsidc.org/cryosphere/sotc/sea_ice.html

5 Wieslaw Maslowski, Jaclyn Clement Kinney, Matthew Higgins, and Andrew Roberts. "The future of Arctic sea ice." *Annual Review of Earth and Planetary Sciences* 40 (2012): 625-654.

6 "Summary for Policymakers", Figure 7, in *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2013.

7 "Ledokoly 'Atomflota' v navigatsiyu – 2013 obespechili bezopasnyi tranzitnyi perekhod 71 sudna", *Rossiiskoye Sudokhodstvo*, December 12, 2013.

8 *List of NSR transit voyages in 2014 navigational season*, Northern Sea Route Information Office, accessed at http://www.arctic-lio.com/docs/nsr/transits/Transits_2014.pdf>.

9 Tomas Nilsen, "Warmer Arctic could give boost to cruise tourism," *Barents Observer*, April 1, 2014, accessed at http://barentsobserver.com/en/business/2014/04/warmer-arctic-could-give-boost-cruise-tourism-01-04|

10 Nassim Nicholas Taleb, *The Black Swan: The Impact of the Highly Improbable*, (Random House 2007).

11 Northern Sea Route Information Office, 2015, accessed at http://www.arctic-lio.com.

12 "Glavkom VMF: iz pripolyusnykh raionov Arktiki mogut iskhodit novye ugrozy bezopasnosti RF", *Murmanskii Vestnik*, March 21, 2014.

Fish, Food Security and Future Conflict Epicenters

Dr. Michael Thomas[1]

Introduction

Throughout history, fisheries have played a central role in driving economic development and sustaining human livelihoods and health. But their success has also been their Achilles' heel; today fisheries have become ever more contested as nations have increasingly sought both food and economic security in the face of rising demand (population growth) and reduced supply (exhausted stocks, pollution, and species loss). This neo-Malthusian scenario has been somewhat mitigated by the development of an international rules-based approach to fishing governance designed to regulate hauls and access, and provide pathways to avoid confrontation. But this balancing act has now come under increasing pressure from both climatic and non-climatic factors that are driving unprecedented changes to fish numbers, species composition, distribution, range and yield. Climate drivers are presenting new and unprecedented risks to fisheries, including increasing sea temperatures, ocean acidification, sea-level rise and changes to surface and deep water currents. These changes may could become a proximate cause and/or tipping point for resource conflicts as countries and companies pursue dwindling fish stocks that — accelerated by climate change — are also moving beyond sovereign Exclusive Economic Zones (EEZ) and traditional fishing grounds. Furthermore, conflict over fisheries in one part of the world can have impacts on regions and economies thousands of miles away, and are now central to understanding the unique security challenges of the Anthropocene.

A Brief History of Fisheries Governance and Contemporary Disputes

Fisheries have been and continue to be a central part of the human story.[2] Paleo-studies suggest fish have been important to the human diet throughout our evolutionary history,[3] and multiple studies have emphasized their continued importance to food security.[4,5,6,7] Beyond their important place in our evolutionary and civilizational history, fisheries are an essential part of the modern global economy. Annual catches of fish are nearing 100 million tons by an industry that indirectly supports the livelihood of more than 1.5 billion people and supplies 3.1 billion people with 20% of their protein requirements.[8] As global population is expected to reach 9.7 billion by 2050, fisheries will remain a crucial pillar of food security. Annually, the fisheries contribute more than USD$270 billion to global GDP and, of the 120 million full-time and part-time people employed by the fishing sector, roughly 47% are women and 97% are in developing countries.[9] More than just a mere food source, fisheries have been, and continue to be, fundamental to global economic development and human health.

Viewed this way, it is axiomatic that any substantive variation to fisheries (such as changing availability, reduced yields, loss of access to fishing grounds, increased competition, as well as changing fish ranges, distribution and species loss) has the potential to significantly impact human, national and — in extremis — international security. This has been recognized since at least the 1950s when the exponential growth of the fishing industry — from local near-shore fishing fleets to the rise of industrial-scale flotillas (about 4.6 million fishing vessels in 2014) — necessitated a lattice of international conventions and agreements designed to regulate catch and avoid confrontation through the promotion of a rules-based approach.[10] This idea has been especially significant for the high-seas, where the tyranny of distance and limited sovereign jurisdiction renders entire areas susceptible to illegal, unreported, unregulated (IIU) fishing.[11] Despite all of this, the agency and effectiveness of international fishing laws, norms and institutions have been limited by the voluntary nature of nations acceding to the various agreements and to the complexities and challenges associated with enforcement. The point that almost one-third of world's fish stocks are overfished and that marine populations have declined by almost 50% since 1970 lends urgency to resolving the structural challenges of fishing governance.[12, 13]

The rise of an international, rules-based fishing order has, on occasion, been sorely tested in more direct ways. Between 1952 and 1976, the so-called 'Cod Wars' saw Britain and Iceland repeatedly square off over disputed access to fishing grounds in the North Atlantic. Characterized by major public demonstrations, ramming of ships at sea, and the deployment of opposing naval forces, the conflict climaxed when Iceland threatened to leave NATO, thereby exposing Europe to Soviet submarines operating across the Greenland-Iceland-UK (GUIK) gap.[14]

Similar disputes have also occurred between France and Brazil (the so-called 'Lobster Wars' in the early 1960s);[15] in 1993 between France and Britain (the 'Cherbourg Incident');[16] and in 1996 between Canada and Spain over fishing rights on the Grand Banks of Newfoundland (the 'Turbot War').[17] The Mediterranean has also repeatedly been a region of intense disputes exacerbated by over-exploitation of fisheries for the past 50 years and disputes over maritime boundaries.[18] The region has lost 41% of its marine mammals and 34% of its total fish population[19] Morocco and the European Union (EU) have, since the 1970s, had several major disputes over fishing ground access and claims of over-fishing. Likewise for Spain and the UK, while the ongoing dispute between Turkey and Greece in the Aegean Sea originated, in part, over fishing rights.[20]

More recently, Vietnam and China have repeatedly clashed over fishing rights in the South China Sea, including a 2005 incident where Chinese patrol boats opened fire on Vietnamese fishing trawlers, killing nine crewmen, reminiscent of a 1988 incident in which 64 Vietnamese were killed.[21] With multiple overlapping and competing territorial claims and large populations dependent on fisheries and other resources, violent incidents and military brinkmanship between multiple nations in the South China Sea remain persistent and unresolved.[22]

Despite the seriousness of these disputes and associated structural challenges, one mitigating factor (variability aside) has been the constancy of the climate. But this dependability — a bedrock of fisheries and human livelihood for millennia — can no longer be relied upon.

Climate Change: A New Factor in Fisheries

New Physical and Chemical Characteristics

Climate change is now widely recognized as a major factor shaping the world's oceans, posing a threat to global fisheries and the existing international rules-based approach.[23] Central to this is the unprecedented change in the underlying physical characteristics of the world's oceans. Since the 1980s ocean heat content has increased by 15 x 10^{24} joules or roughly 270 times the total amount of energy used by all the people on Earth for one year (Figure 1).[24] This is increasing ocean sea-surface temperatures (0.11°C per decade 1971-2010 for the upper 75m) and is a contributing factor to sea-level rise through thermal expansion and its role in melting sea-ice, particularly across the Arctic.[23] Climate change is also causing the world's oceans to become more acidic, driving changes in salinity levels, altering oxygen and carbon concentrations, and affecting the variability of the planet's major ocean surface currents and deep-water circulation systems.[24]

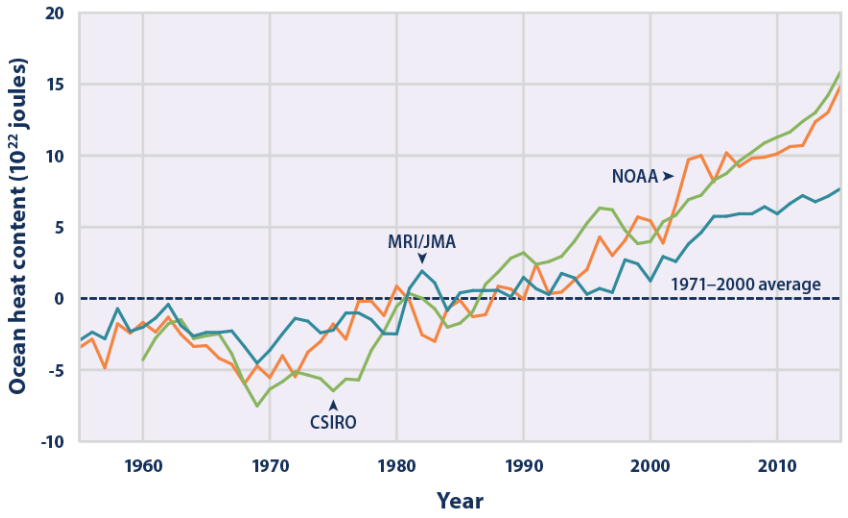


Figure 1: Climate change is driving up global ocean heat content. Source: US EPA.[25]

Such changes are negatively impacting fish physiology, phenology, and behavior, resulting in changes to spatial distribution, productivity, species numbers and composition.[25] Some studies, for instance, estimate that ocean warming and shifts in net primary production could lead to a reduction in total global fish catch by 6%, and as much as 30% in the tropics, by 2050.[26] Others have assessed that ocean warming in association with declining oxygen levels could reduce the body weight of fish by 14-24% globally, with a 20% reduction in fish biomass experienced across the tropics.[27]

Climate change is also particularly damaging to coral reef and mangrove systems;[28] often considered as the engine rooms of marine productivity, wherein they serve as incubators and as oases for larger pelagic fish and marine mammals.[29] The overall changes imposed by climate change on the oceans are crucial from a food security perspective, particularly across developing nations, where fish accounts for some 20% of the daily diet (by weight) for 1.39 billion people, and where creating access to alternative sources of micronutrients often is beyond the capacity of poor local communities, much less weak states.[30] In this challenged ecosystem – where denuded marine ecosystems, already under stress from over-exploitation, IIU, industrial pollution and poor governance, rapidly translate into loss of income, livelihood and in some cases malnutrition of communities that rely on fish as a key source of nutrition,[31] – climate change stands to be a major threat to global food and economic security.

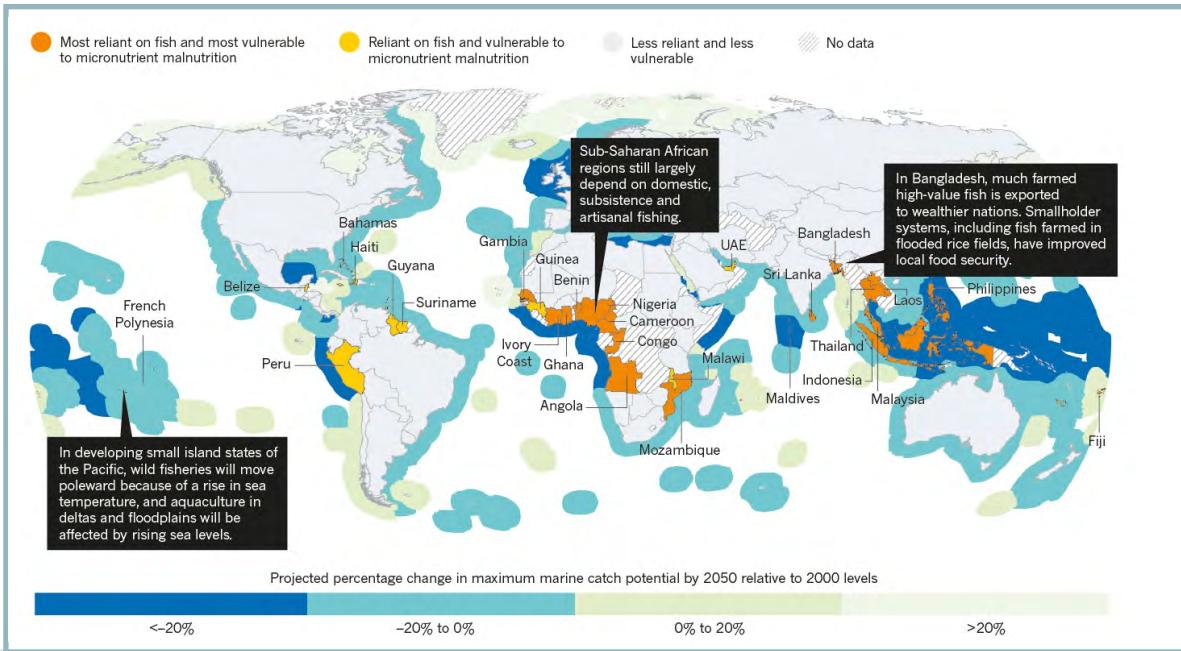


Figure 1: Changes in marine catch as a result of climate change and other factors is projected to be acutely felt across the equatorial belt and in developing countries. Source: Nature.[32]

New Extremes

Climate change is also driving more extreme events, laying waste not only to marine habitats but also to the critical infrastructure (vessels and ports) required to support fisheries' livelihoods. Related to this is the prospect of larger and more intense *El Nino* and *La Nina* that are harbingers of more extreme droughts, cyclones, floods, wildfires and downpours across the planet.[33] This is also the case in the marine environment, as evinced by the 1972/73, 1982/83 and 1997/98 *El Nino* that witnessed decreased catch, surging fish prices, and adverse economic consequences.[34]

In particular, extreme *El Nino* and *La Nina* events have the ability to significantly disrupt marine nutrient supplies (such as phytoplankton and zooplankton) that are critical to virtually all higher forms of marine life.[35, 36] While disruptions to nutrient supply related to the Peruvian Current are well known under *El Nino* conditions, a recent study found that nutrient production in the South China Sea also was suppressed under extreme *La Nina* conditions,[37] which due to climate change, could potentially increase in frequency.44 Ultimately, less nutrients means smaller and fewer fish. As history has shown, this usually leads to one of two outcomes: increased competition and tensions over existing fishing grounds, or a move by foreign fleets to exploit new locations.

On the latter point, a recent report highlighted how Chinese Distant Water Fishing (DWF) companies have pushed into West African waters, exploiting the lax maritime enforcement and costing West African economies $2 billion a year.[38] In the case of Senegal, fish prices have soared as scarcity has increased due to the presence of destructive Chinese bottom trawlers that sap 40,000 tons of fish a year from their waters. Already gripped by climate-related drought, the decline of the Senegalese fishing sector has led to economic and food security concerns that have been cited as one factor in driving their youth to make the hazardous journey to Europe and adding to existing migrant tensions and instability across the continent.[39]

Fish Security Epicenters

Three global "fish security epicenters" have emerged where climate change has the potential to significantly impact regional and global security: the South China Sea (SCS), the Arctic,[41] and the African great-lakes.[42]

Figure 2: With local waters exhausted, China has deployed its Distant Water Fleet (DWF) into other areas around the globe, reducing fish stocks and impacting food and economic security for littoral nations.
Source: Greenpeace.[40]

The South China Sea

The SCS is an area fraught with security dilemmas. While energy resources are often cited as a factor,[43] fisheries plays a major — if not defining — role.[44] An overview captures the high-stakes: the area is home to more than 3,360 marine species, generates 12% of the world's catch, worth $21.8 billion, employs almost 4 million people and feeds hundreds-of-millions more. 55% of the world's fishing fleet operates in an area that possesses an increasingly dwindling resource base that has seen a 70% to 95% depletion since the 1950s.[45] Moreover, competition among nations has been manifest for decades, and fishing fleets are widely regarded as proxies for staking maritime claims. Arguably, China is the most advanced and uses its 200,000-strong fishing fleet as a "maritime militia," operating with impunity as an irregular naval force, claiming islands, ferrying goods and materials to assist the PLA in port and military-base construction, and collecting maritime intelligence inside the so-called nine-dashed line.[46] However, while many point to aggressive Chinese tactics, other littoral nations have been equally bold. Indonesia, Vietnam, Malaysia and the Philippines have all blown up or threatened to blow up vessels that enter "their" waters and regularly use their navies to intercept and destroy foreign fishing vessels.[47, 48]

It is in this overall context that climate change has emerged as an SCS threat-multiplier, layering existing problems with new dilemmas that serve as a further catalyst for conflict. This can occur in several ways. First, climate change has the potential to cause SCS fish stocks to migrate away from the region, potentially causing fleets to pursue stocks into more northern (Taiwan Strait, East China Sea, or Sea of Japan), southern (Indonesian archipelago) or eastern waters (Philippine Sea). In such a tight operating space, with hundreds of thousands of fishing vessels, unresolved territorial claims and depleted fish stocks, even the slightest migrations present risk. Second, climate change has the potential to reduce SCS marine productivity through coral

bleaching, habitat destruction and changes in nutrient production. In the absence of alternatives, particularly for those nations lacking distant water fleets, reduction to fisheries productivity exposes millions to food and economic insecurity.

The Arctic

More than any other region on the planet, the Arctic is being transformed by climate change. The narrative, by now, is an unhappily familiar one: the region is warming twice as fast as the global average and summer sea-ice has been declining more than 10% per decade since 1979[49] such that it is "likely" to be ice-free by summer 2050, 24 with some estimates as early as 2030.[50] The loss of ice has produced a negative feedback loop, in which an increasing amount of the sun's energy is being absorbed rather than reflected. No longer the global refrigerant, increased temperatures have triggered widespread tundra-melt, hastening the release of stored methane, which acts as an accelerant to climate change. In lock-step with these changes has been increased interest by nations to exploit the Arctic's increasing accessibility and accompanying socioeconomic opportunities. Foremost, they seek shorter shipping routes that connect the global commodity markets of Europe with Asia-America and offer the opportunity to exploit untapped natural resource deposits, fishing, tourism opportunities and scientific expeditions.[51] As countries position themselves, national military forces are being marshaled as a means to secure these opportunities. Military force projection into the region and future expansion plans by the militaries of Russia, the US, Canada, Norway and others have fed perceptions that the Arctic is being unnecessarily "securitized," with the possibility that it may lead to grave misunderstandings. The possibly of the Arctic as a future theater of conflict has not been dismissed.

Fisheries form a part of this increasingly fraught climate-security scenario. Marine ecosystems, like their surface counterparts, have also warmed twice as fast as the global average, prompting a pole-wards shift of migratory fish out of the north-Pacific and Barents Sea at an "invasion intensity" rate five-times the global average.[52] The arrival of "generalist" fish is causing a retraction and deterioration of existing Arctic species that may ultimately lead to disruption, even the destruction and extinction, of local ecosystems and fish varieties. Of particular interest is the movement of commercially popular species such as cod and haddock, as well as projections that fish size may actually increase (figure 3), which could make the region increasingly attractive to non-arctic fishing fleets. In this instance, the unwelcomed and increased presence of foreign fishing fleets moving into an area of unresolved maritime disputes poses additional challenges for the region.

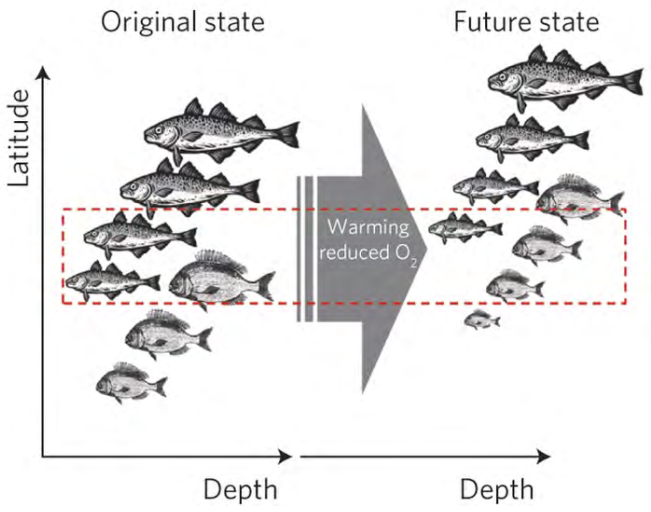


Figure 3. Projected changes in expected biological responses of fish communities in terms of distribution and body size.

Source: Nature.[53]

The Great Lakes

While much focus is on the impact of climate change on the world's oceans, climate change is also impacting inland lakes, rivers and estuaries, which represent a new dimension to fish and food security. Nowhere is this more prevalent than in the African Great Lakes region. Located in the East African rift valley region, the African Great Lakes are a vast collection of lakes[54] that possess 25% of the planet's freshwater supply, 10% of its fish species, and a source of food and economic security to some 107 million people. This affects almost a dozen countries, including some of the most crisis-stricken in the Democratic Republic of Congo, Burundi, Rwanda, Uganda, Kenya, Tanzania, Zambia, Mozambique and Ethiopia.[55]

The importance of the lakes to livelihoods and national economies cannot be underestimated. To take one example, Lake Tanganyika yields up to 200,000 tons of fish per annum and supplies about 60% of the region's protein consumption.[56] Nonetheless, it is a region in the balance, wracked as it is by poverty, terrorism, corruption, poor governance, unemployment, population growth, resource scarcity and violent conflict. Climate change presents as an additional threat multiplier that exacerbates these challenges. While the effects of climate change on precipitation patterns, desertification, temperatures, drought and extreme events are well documented across Africa, it will also be detrimental to fisheries through declining fish and mollusk species, reduced mixing and upwelling events leading to suppressed nutrient supply, and impacts on fish habitats through increased temperatures, decreased dissolved oxygen levels and increased toxicity.[57]

Negative impacts on the Great Lake fisheries will have significant consequences for regional food and economic security, particularly given the litany of existing problems, but also because of the high reliance of the population on fish as a fundamental source of nutrition, employment and livelihoods, income and government revenues through fisheries agreements and taxes.[58] A decline in fisheries risks malnutrition, unemployment and reduced incomes, which serves to increase societal stress and state fragility.

Such conditions are ripe for exploitation by either entrenched elites or, as has occurred further north around Lake Chad, by terrorist groups and insurgents. Lake Chad has been severely stressed by climate change; over the past 50 years it has lost 90% of its surface with the prospect that it could disappear within 20 years. As the region's economic and cultural anchor point, which sustains some 30 million people, such an event not only would have devastating security consequences, especially in Africa, but also would drive desperate migrants across the Mediterranean to Europe. In part, these issues are already playing out in the form of Boko Haram, the terrorist group that preys on poor and underemployed youth, which has already claimed some 20,000 lives.[59]

Conclusion

Fisheries are central to human existence. Climate change has the potential to act as a major disrupter to fish stocks, distribution and composition. While conflict over fish has been a constant feature of international relations, climate change is poised to introduce large-scale changes unmatched in recorded history. The ability of governance frameworks and institutions to manage these changes remains, at best, a fragile and uncertain bet. Preventing conflict over fisheries and maintaining food security from fish protein will require better understanding and preparation for the confluence of risks. The current international rules in place to regulate fishing do not do enough to accommodate a changing climate. Food and fishery security and the possibility of these conflicts scaling up to higher order security risks, suggests that this issue be prioritized.

Notes

1 Senior Fellow for Security Sector Education, The Center for Climate and Security

2 T. J Pitcher and M.E. Lam, *Fish commoditization and the historical origins of catching fish for profit.* Maritime Studies, 2015. 14(2).

3 M.T. Arts, R.G. Ackman, and B.J. Holub, *"Essential fatty acids" in aquatic ecosystems: a crucial link between diet and human health and evolution.* Canadian Journal of Fisheries and Aquatic Sciences, 2001. 58(1): p. 122-137.

4 FAO, *The State of World Fisheries and Aquaculture: Contributing to Food Security and Nutrition for All.* 2016: Rome. p. 200.

5 S.H Thilsted, et al., *Maximizing the contribution of fish to human nutrition* in *ICN2 International Conference on Nutrition.* 2014, FAO: Rome.

6 D. Weitz, et al., *Fish Oil for the Treatment of Cardiovascular Disease.* Cardiology in review, 2010. 18(5): p. 258-263.

7 A. Nyaradi, et al., *The role of nutrition in children's neurocognitive development, from pregnancy through childhood.* Frontiers in Human Neuroscience, 2013. 7: p. 97.

8 FAO, *The State of World Fisheries and Aquaculture: Contributing to Food Security and Nutrition for All.* 2016: Rome. p. 200.

9 World Bank, *Hidden Harvest: The Global Contribution of Capture Fisheries.* 2012, World Bank: Washington, DC.

10 FAO, *The State of World Fisheries and Aquaculture: Contributing to Food Security and Nutrition for All.* 2016: Rome. p. 200.

11 NOAA. *Illegal, Unreported, and Unregulated (IUU) Fishing*. NOAA Fisheries 2017 [cited 2017 5 April]; Available from: http://www.nmfs.noaa.gov/ia/iuu/iuu_overview.html.

12 FAO, *The State of World Fisheries and Aquaculture: Contributing to Food Security and Nutrition for All*. 2016: Rome. p. 200.

13 WWF, *Living Blue Planet Report: Species, habitats and human well-being*, J. Tanzer, et al., Editors. 2015: Switzerland.

14 HM Government, *Cod Wars,* N. Archives, Editor. 2017, HM Government: London.

15 Azzam, I., *The Dispute Between France and Brazil over Lobster Fishing in the Atlantic*. International and Comparative Law Quarterly, 2008. 13(4): p. 1453-1459.

16 BSF. *The Cherbourg Dispute*. 2017 [cited 2017 5 April]; Accessed at: http://britishseafishing.co.uk/the-cherbourg-dispute/.

17 M.S. Soroos, *The Turbot War: Resolution of an International Fishery Dispute*, in *Conflict and the Environment,* N.P. Gleditsch, Editor. 1997, Springer Netherlands: Dordrecht. p. 235-252.

18 Piroddi, C., et al., *Historical changes of the Mediterranean Sea ecosystem: modelling the role and impact of primary productivity and fisheries changes over time*. Scientific Reports, 2017. 7: p. 44491.

19 Ibid.

20 B. Yesilada, *EU-Turkey Relations in the 21st Century*. 2013, Oxon: Routledge.

21 N.Q. Thong, *Deadly fight against Chinese for Gac Ma Reef remembered*, in *Thanh Nien News*. 2013, Thanh Nien News: Vietnam; M. Petty, *Vietnam protesters denounce China on anniversary of navy battle*, in *Reuters*. 2016, Thomson Reuters; Pham, V., *The Use or Threat of Force in teh South China Sea Disputes Since 1945: A Timeline*. Power Politics in Asia's Contested Waters: Territorial Disputes in the South China Sea, ed. X. Gu. 2016, London: Springer.

22 Pham, V., *The Use or Threat of Force in the South China Sea Disputes* Since 1945: A Timeline. Power Politics in Asia's Contested Waters: Territorial Disputes in the South China Sea, ed. X. Gu. 2016, London: Springer.

23 GBRMPA. *Climate change impacts on the ocean habitat*. 2017 [cited 10 April 2017]; Accessed ats: http://www.gbrmpa.gov.au/managing-the-reef/threats-to-the-reef/climate-change/what-does-this-mean-for-habitats/open-ocean.; A.B. Hollowed, et al., *Projected impacts of climate change on marine fish and fisheries*. ICES Journal of Marine Science, 2013. 70(5): p. 1023-1037.; A.L. Green, et al., *Designing Marine Reserves for Fisheries Management, Biodiversity Conservation, and Climate Change Adaptation*. Coastal Management, 2014. 42(2): p. 143-159.

24 A.L. Green, et al., *Designing Marine Reserves for Fisheries Management, Biodiversity Conservation, and Climate Change Adaptation*. Coastal Management, 2014. 42(2): p. 143-159.

25 EPA. *Climate Change Indicators: Ocean Heat*. [Data from CSIRO; MRI/JMA; NOAA] 2017 [cited 2017 15 April]; Accessed at: https://www.epa.gov/climate-indicators/climate-change-indicators-ocean-heat.

26 Ibid.

27 W.W.L. Cheung, R. Watson, and D. Pauly, *Signature of ocean warming in global fisheries catch*. Nature, 2013. 497(7449): p. 365-368.

28 Cheung, et al., *Structural uncertainty in projecting global fisheries catches under climate change*. Ecological Modelling, 2016. 325: p. 57-66.

29 Cheung, et al., *Shrinking of fishes exacerbates impacts of global ocean changes on marine ecosystems*. Nature Clim. Change, 2013. 3(3): p. 254-258.

30 P.L. Jokiel, *Predicting the impact of ocean acidification on coral reefs: evaluating the assumptions involved*. ICES Journal of Marine Science, 2016. 73(3): p. 550-557; K.J. Kroeker, et al., *Impacts of ocean acidification on marine organisms: quantifying sensitivities and interaction with warming*. Global Change Biology, 2013. 19(6): p. 1884-1896.; S.J. Youn, et al., *Inland capture fishery contributions to global food security and threats to their future*. Global Food Security, 2014. 3(3–4): p. 142-148.; R.D. Ward, et al., *Impacts of climate change on mangrove ecosystems: a region by region overview*. Ecosystem Health and Sustainability, 2016. 2(4): p. e01211-n/a.

31 G.P. Asner, R.E. Martin, and J. Mascaro, *Coral reef atoll assessment in the South China Sea using Planet Dove satellites*. Remote Sensing in Ecology and Conservation, 2017: p. n/a-n/a.

32 C.D. Golden, et al., *Nutrition: Fall in fish catch threatens human health*. Nature, 2016. 534(7607): p. 317 - 320.

33 Ibid.

34 Ibid.

35 K. Dahlin and T. Ault, *Climate Teleconnections and the Biosphere*. American Geophysical Union, 2015. Fall.; N.C. Lau, A. Leetmaa, and M.J. Nath, *Interactions between the Responses of North American Climate to El Niño–La Niña and to the Secular Warming Trend in the Indian–Western Pacific Oceans*. Journal of Climate, 2008. 21(3): p. 476-494.; W. Cal, et al., *ENSO and greenhouse warming*. Nature Clim. Change, 2015. 5(9): p. 849-859.

36 OECD, *The Economics of Adapting Fisheries to Climate Change*. 2010, Paris: OECD Publishing.

37 M. Steinacher, et al., *Projected 21st century decrease in marine productivity: a multi-model analysis*. Biogeosciences, 2010. 7(3): p. 979-1005.

38 D.G. Boyce, et al., *Estimating global chlorophyll changes over the past century*. Progress in Oceanography, 2014. 122: p. 163-173.

39 K.K. Liu, et al., *Inter-annual variation of chlorophyll in the northern South China Sea observed at the SEATS Station and its asymmetric responses to climate oscillation*. Biogeosciences, 2013. 10: p. 7449–7462.; Y. Zhang, Y. and K. Yin, *Fish Catch and Nutrient Limitation in the South China Sea*.; Zhang and Yin. *Fish Catch and Nutrient Limitation in the South China Sea*. in *International Conference on Plant, Marine and Environmental Sciences (PMES-2015)* 2015. Kuala Lumpur (Malaysia).

40 A. Doumbouya, et al., *Assessing the Effectiveness of Monitoring Control and Surveillance of Illegal Fishing: The Case of West Africa*. Frontiers in Marine Science, 2017. 4(50).

41 A. Jacobsapril, *China's Appetite Pushes Fisheries to the Brink*, in *New York Times*. 2017, Arthur Ochs Sulzberger Jr.: New York.

42 Greenpeace, *Africa's Fisheries Paradise at a Crossroads: Investigating Chinese Companies' Illegal Fishing Practices in West Africa*. 2015, Greenpeace: Beijing.

43 P. Wassmann, et al., *Footprints of climate change in the Arctic marine ecosystem*. Global Change Biology, 2011. 17(2): p. 1235-1249.

44 C.M. O'Reilly, et al., *Climate change decreases aquatic ecosystem productivity of Lake Tanganyika, Africa*. Nature, 2003. 424(6950): p. 766-768.; M.R. Ndebele-Murisa, E. Mashonjowa, and T. Hill, *The implications of a changing climate on the Kapenta fish stocks of Lake Kariba, Zimbabwe*. journal= "", 2011. 66(2): p. 105-119.; M.C. Badjeck, et al., *Impacts of climate variability and change on fishery-based livelihoods*. Marine Policy, 2010. 34(3): p. 375-383.

45 S.L Montgomery, *What's at stake in China's claims to the South China Sea?* 2016 [cited 2017 17 April]; Accessed at: https://theconversation.com/whats-at-stake-in-chinas-claims-to-the-south-china-sea-62472.

46 Pham, V., *The Use or Threat of Force in the South China Sea Disputes Since 1945: A Timeline*. Power Politics in Asia's Contested Waters: Territorial Disputes in the South China Sea, ed. X. Gu. 2016, London: Springer.

47 C. Schofield, R. Sumaila, and W. Cheun. *Fishing, not oil, is at the heart of the South China Sea dispute*. 2016 [cited 2017 1 March]; Accessed at: https://theconversation.com/fishing-not-oil-is-at-the-heart-of-the-south-china-sea-dispute-63580.

48 J. Kraska, *China's Maritime Militia Upends Rules on Naval Warfare: The use of fishing vessels as a maritime militia has profound legal implications*. 2015 [cited 2017 20 March]; Accessed at: http://thediplomat.com/2015/08/chinas-maritime-militia-upends-rules-on-naval-warfare/.

49 Pham, V., *The Use or Threat of Force in the South China Sea Disputes Since 1945: A Timeline*. Power Politics in Asia's Contested Waters: Territorial Disputes in the South China Sea, ed. X. Gu. 2016, London: Springer.

50 C. Schofield, R. Sumaila, and W. Cheun. *Fishing, not oil, is at the heart of the South China Sea dispute*. 2016 [cited 2017 1 March]; Accessed at: https://theconversation.com/fishing-not-oil-is-at-the-heart-of-the-south-china-sea-dispute-63580.

51 A.B. Farré, et al., *Commercial Arctic shipping through the Northeast Passage: routes, resources, governance, technology, and infrastructure*. Polar Geography, 2014. 37(4): p. 298 - 324.

52 M. Fossheim, et al., *Recent warming leads to a rapid borealization of fish communities in the Arctic*. Nature Clim. Change, 2015. 5(7): p. 673-677.

53 Cheung, et al., *Shrinking of fishes exacerbates impacts of global ocean changes on marine ecosystems*. Nature Clim. Change, 2013. 3(3): p. 254-258.

54 Lake Victoria, Lake Tanganyika, Lake Malawi, Lake Turkana, Lake Albert, Lake Rukwa, Lake Mweru, Lake Kivu and Lake Edward.

55 New World Encyclopedia. *African Great Lakes*. 2016 [cited 2017 2 April]; Accessed at: http://www.newworldencyclopedia.org/entry/African_Great_Lakes.

56 A.S. Cohen, et al., *Climate warming reduces fish production and benthic habitat in Lake Tanganyika, one of the most biodiverse freshwater ecosystems*. Proceedings of the National Academy of Sciences, 2016. 113(34): p. 9563-9568.

57 C.M. O'Reilly, et al., *Climate change decreases aquatic ecosystem productivity of Lake Tanganyika, Africa*. Nature, 2003. 424(6950): p. 766-768.; A.S. Cohen, et al., *Climate warming reduces fish production and benthic habitat in Lake Tanganyika, one of the most biodiverse freshwater ecosystems*. Proceedings of the National Academy of Sciences, 2016. 113(34): p. 9563-9568.; A.D. Ficke, C.A. Myrick, and L.J. Hansen, *Potential impacts of global climate change on freshwater fisheries*. Reviews in Fish Biology and Fisheries, 2007. 17(4): p. 581-613.

58 G.D. Graaf and L. Garibaldi, *The Value of African Fisheries*. 2014, FAO: Rome

59 K. Nett and L. Rüttinger, *Insurgency, Terrorism and Organised Crime in a Warming Climate Analysing the Links Between Climate Change and Non-State Armed Groups*. 2016: Berlin.

Climate, Coffee and Security

Shiloh Fetzek[1]

Introduction

Many people view climate change as an abstract threat to other, faraway persons in the distant future. Take away their morning cup of coffee, though, and they may come to realize that climate change is happening here, now, to us. But the likely impacts and consequences of the threat climate change poses to coffee don't stop with a more expensive or less reliable cup of morning of coffee. Climate change's impact on coffee production could drive broader social and security risks, and disrupt the intricate and fragile relationship between coffee farming and economic, social, political and regional security.

Climate change will have a dramatic effect on the coffee market. One estimate suggests that half of the land suited to production of the Arabica beans that form the mainstay of the coffee trade will no longer be suitable for growing coffee by 2050.[2]As a crop, coffee is highly vulnerable to climate-related pests and diseases, with an outbreak of the fungal disease coffee leaf rust causing Guatemala, El Salvador and Honduras to declare national emergencies in 2013. As the climate changes, it will cause unpredictable shifts in exposure to pests and diseases that will complicate efforts to insulate the industry from climate impacts.

There is often an overlap between the areas where these adverse impacts are projected to be most severe and countries with the highest percentage of GDP derived from coffee exports. Many of these countries also face underlying security fragilities, such as a history of recent conflict, serious organized crime, weak state institutions, chronic poverty, food insecurity, and rapid urbanization, often in combination with high

unemployment and burgeoning youth populations. The loss of a vital cash commodity crop for some of the poorest and most vulnerable citizens in these countries, and the detrimental effect on foreign exchange and GDP for their national economies, threatens to exacerbate such underlying fragilities and – in some cases – impact the drivers of insecurity in ways that could scale up to broader regional security concerns.

Despite some economic traits unique to coffee, a similar analysis could be done for any globally traded food crop or any crop that contributes to regional food and economic security. But, unlike with staple foods such as cereals, (which for many communities are necessary for survival), coffee, and the climate-exacerbated shocks to the communities that depend on it for their livelihoods, are not typically factored into analysis of state fragility or regional insecurity. In this context, it is possible that the potential security repercussions of a climate-related crash in coffee production could be overlooked, raising the risk that coffee crop failures become black swan events that would be easy to miss while focusing on arguably more immediate threats to staple crops.

Coffee Production in a Changing Climate: Supporting 25 Million Farmers

Coffee is one of the world's most important agricultural commodities and the primary source of income for 125 million people globally.[3] Coffee beans are a labor-intensive, high-value crop that can maximize earnings from small landholdings, although coffee growers and laborers regularly endure hardships associated with this volatile commodity market. Ninety percent of the coffee that is traded is produced by smallholders, and it is on these small producers that damage to the coffee industry from climate change will fall most heavily, particularly as a large majority of the 25 million farmers who produce coffee may have few agricultural alternatives to provide their livelihoods.[4]

While coffee production has matured with time and technology, growing coffee berries has always been a delicate process. The coffee plant is highly sensitive to temperature and rainfall variations and has a narrow range of optimal conditions, outside of which bean quality and yield decline. Coffee flowers bloom only for about 48 hours, and the plant is vulnerable to disease and pests. Both *Coffea arabica* L. (Arabica) and *Coffea canephora*, syn. *Coffea robusta* (Robusta) require stable, predictable climatic conditions to flourish. Arabica is the higher-value variety that accounts for around 60% of export volume[5] and is the preferred choice for smallholders who produce coffee for export.

The stable, predictable, climate conditions that enable coffee production are projected to become less stable and predictable. Regional warming and increasingly erratic rainfall have already increased the frequency of poor coffee harvests in many countries, affecting regional and global prices. Further climate change will alter the geographic distribution of areas suitable for growing both main varieties of coffee. By 2050, the

warming climate could shift the optimal altitude for coffee production from 1,400 m (in 2020) to 1,600 m.[6] As the climate zones suitable for coffee production gradually "climb up the mountain," new geographies for coffee production will emerge as production becomes viable for higher-altitude smallholdings, while farmers at lower altitudes may no longer be able to produce their cash commodity crop.[7]

But any new opportunities to grow coffee may be short-lived as the climate continues to change and geographical suitability continues to shift. Investment in coffee trees and trade systems take 8-15 years to come to fruition,[8] reducing the window of opportunity for smallholdings that find themselves passing through a climate optimal zone, making planning for such shifts difficult. While the few, large trading and roasting companies will continue to purchase from wherever coffee beans are available, smallholders are less flexible. Without adaptation or crop diversification small producers will lose income, but even successful adaptation to the impacts of climate change on coffee production will increase costs, whether it is from purchasing pesticides and fungicides, diversifying crops, installing irrigation systems or planting shade trees. Smaller producers already tend to have more limited resources,[9] and declining crop yields and quality will put further strain on their finances. In turn, this may impair their ability to respond to disease outbreaks or undertake other climate adaptation measures, creating a vicious cycle that may be difficult to reverse.

The potential loss of income for small coffee growers and laborers from climate-driven shifts in agriculture threatens not only the economic security of households across coffee-producing regions, but could also have a significant impact on national economies in a number of developing countries. In a climate-disturbed world, this temperamental bean that supports the livelihoods of millions could become an increasingly unreliable bet.

Climate-related pathogen – coffee leaf rust

Coffee leaf rust (*Hemileia vastatrix*), illustrates the potential of climate-driven damage to coffee production as an epicenter of risk. This climate-related fungal disease infects and destroys the leaves of Arabica coffee trees, impeding photosynthesis and gradually killing the trees. The fungus cannot survive below 50°F/10°C, which previously limited its spread above elevations of 1,600 m. Warm, humid conditions, rainy weather and warming night-time temperatures have expanded this ceiling to 2,000 m, bringing more coffee plantations within its reach. Historically, leaf rust has been a manageable risk because it is limited to certain elevations and climatic conditions. However, as with other climate-exacerbated stresses, the coping and risk management methods that have been developed for historic climates are unlikely to remain reliable.

Risk zone – Central America

Coffee is the most profitable export crop in coffee-growing regions of Central America. The industry directly employs more than 2 million people in Central America and the Caribbean, with hundreds of thousands more employed by suppliers and in service industries.

A severe outbreak of coffee leaf rust in 2012/2013 impacted half of the approximately 1 million acres of coffee cultivated in Central America. Occurring simultaneously with a global fall in coffee prices, it meant Guatemala, El Salvador and Honduras saw the total value of their export coffee crops decline from about US$3.4 billion in 2011/12 to US$1.6 billion in 2013/14. The region saw more than half a million job losses and all three countries declared national states of emergency.[10]

While the reasons for the severe 2012/3 leaf rust outbreak are complex, a 30% fall in coffee prices resulting from broader market issues contributed to poor institutional and farmer capacity to respond effectively to the early stages of the outbreak[11] and limited funds available for fungicide and fertilizer to strengthen trees. It is likely that increased climate variability was an important factor behind the scale of the outbreak.[12]

For smallholders and harvesters in this region, income from coffee is essential for purchasing food and supplies for the cultivation of staple grains.[13] The loss of income that accompanied the leaf rust outbreak caused significant food insecurity, with the Famine Early Warning Systems Network and World Food Program both warning of potential famine.[14] These dynamics acted as push factors for both internal (primarily urban) and cross-border migration, a routine coping strategy for Central Americans in the agricultural sector to improve food security but one that makes migrants vulnerable to human traffickers and which can exacerbate underlying security fragilities. The coffee rust epidemic, as part of the wider context of economic stagnation and poverty, was one potential factor contributing to the 2014 surge in unaccompanied minors seeking to enter the United States, almost all of whom came from Guatemala, El Salvador or Honduras.[15]

These trends are layered on top of pre-existing tensions and vulnerabilities. Mesoamerica, and these "Northern Triangle" countries in particular, struggle with narcotrafficking and serious organized crime resulting in some of the highest murder rates in the world.[16] Youth who find themselves unemployed in urban areas may have few economic options other than getting involved with gangs, and the level of gang activity and violence can, in turn, act as a push factor for migration as well as limit economic growth and compromise state capacities.

Potential fragility repercussions of climate impacts on coffee

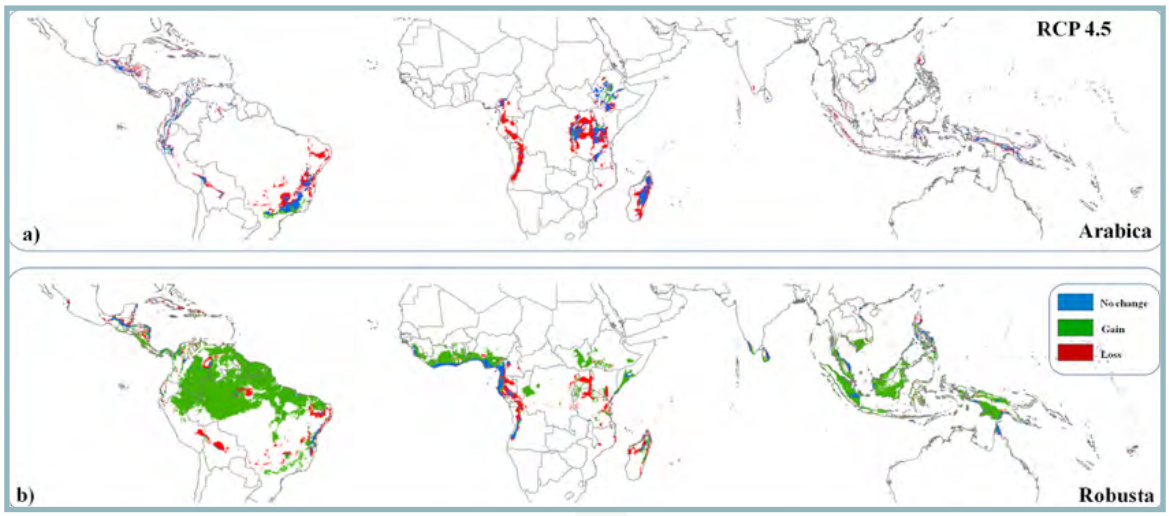
Not all regions where climate change will significantly affect coffee production have the underlying security dynamics of Central America. However, because so much coffee is grown by small producers, climate-driven disruption to coffee production is likely to impact livelihoods and economic security, and have socioeconomic repercussions wherever it occurs. That includes in other regions with underlying security fragilities, where the effect of unemployment, contracting livelihoods and poverty on local security will emerge in context-specific ways.

The gross value of production of green coffee is over US$16 billion annually.[17] The table below indicates the countries in which coffee exports (both green and roasted beans) contributed the highest percentage of GDP from 2003-2013.[18]

	Country	Percentage of GDP from green and roasted coffee exports, averaged over 2003-2013
1	Honduras	4.53
2	Nicaragua	3.24
3	Burundi	2.83
4	Ethiopia	2.33
5	Vietnam	1.88
6	Guatemala	1.67
7	Uganda	1.60
8	Papua New Guinea	1.41
9	El Salvador	1.12
10	Rwanda	1.08
11	Costa Rica	0.95
12	Colombia	0.75
13	Côte d'Ivoire	0.56
14	Peru	0.52
15	Kenya	0.49
16	United Republic of Tanzania	0.39
17	Guinea	0.35
18	Cameroon	0.32
19	Brazil	0.25
20	Jamaica	0.21
21	Togo	0.20
22	Belgium	0.17
23	Switzerland	0.16
24	Indonesia	0.14
25	Madagascar	0.12

Many of the countries that get the most economic benefit from coffee also face underlying fragilities such as a history of recent conflict, weak governance and institutions, rapidly growing youth populations in the context of low economic development and high unemployment, serious organized crime and other security issues.

This map[19] of regions projected to be suitable for Arabica and Robusta cultivation in 2050 helps identify the countries that face the biggest risks to their coffee industries from climate-driven changes in coffee production.



Source: Ainhoa Magrach and Jaboury Ghazoul, "Climate and Pest-Driven Geographic Shifts in Global Coffee Production: Implications for Forest Cover, Biodiversity and Carbon Storage," *PLoS One* (2015)

Countries at particular risk include:

Honduras

Honduras has both the highest percentage of GDP derived from coffee exports and large areas of the country where Arabica is currently cultivated that are projected to become unsuitable by mid-century. A modest increase in areas suitable for Robusta is unlikely to compensate for this loss, which could present a significant challenge to economic growth and development, heavily impacting the livelihoods of smallholder producers. The repercussions of this change could interact with the drivers of instability in Honduras by spurring urban migration and limiting alternative livelihoods, which could increase the likelihood of involvement in illicit economic activity. Honduras's underlying security fragilities include narcotrafficking and serious organized crime, political instability and weak state institutions.

Uganda

20–30% of Uganda's foreign exchange earnings are provided by coffee exports, and 90% of Uganda's export coffee crop is produced by smallholders on farms ranging from 0.5 to 2.5 hectares.[20] A significant segment of the country's population derive their livelihoods directly from coffee production – as such, coffee is also important for income and food security.

The impacts of climate change are already being felt on livelihoods, food security and migration patterns in Uganda.[21] Uganda grows rain-fed Arabica and Robusta coffee varieties, with climate change expected to bring a significant reduction in the area suitable for cultivating both. Uganda's coffee industry does not have a history of responding well to shocks,[22] and disrupted coffee production has the potential to compound underlying fragilities in the country. These include recurring food insecurity, a large and growing youth population, legacy of conflict, emergence of armed rebel groups, the effects of an autocratic government and fractiousness in political parties and election violence.[23]

In countries that face the loss of coffee as a viable export commodity, managing the threat to livelihoods and corresponding security risks might require finding alternative cash crops that can manage in a changing climate. Crops such as cacao might offer a viable alternative in some places, but even successful transitions to other crops will involve an inevitable degree of economic turbulence, and require investment and planning over significant periods of time. In some cases, weak institutional capacity in countries affected by instability and conflict could present a barrier to effective adaptation of the sector.

Steps to minimize adverse outcomes

Managing the risks to livelihoods, economic development and stability posed by the effects of climate change on coffee production will require first and foremost a better understanding of how climate stress to coffee production can increase fragility. If this risk is not being monitored, it could easily be missed by those whose responsibility it is to prepare for and manage shocks and stresses, including increased fragility risk and damage to livelihoods.

There are other measures that are also important to preparing for these changes. These include adapting coffee production through more robust crop varieties, new pest and disease management techniques and strengthening early warning systems. It will also be necessary to support livelihood diversification for producers and to promote local-level adaptation and resilience, particularly where state-level capacities are weak. The coffee industry has begun to incorporate food security concerns into its sustainability agenda and supply chain risk analysis; continuing to do so will help to improve resilience in the face of climate-related risks.

Recent climate impacts on the market have shown that we should prepare for the unexpected in the near-term, and expect major geographic shifts to coffee production in the medium-term. As one of the world's most valuable agricultural commodities, and a highly climate-sensitive crop produced by smallholders in countries facing an array of political and socioeconomic challenges, climate risks to the unassuming coffee bean could have an outsized impact on stability if ignored.

Notes

1 Senior Fellow for International Affairs, The Center for Climate and Security

2 Christian Bunn, Peter Läderach, Juan Guillermo Pérez Jimenez, Christophe Montagnon, Timothy Schilling, "Multiclass Classification of Agro-Ecological Zones for Arabica Coffee: An Improved Understanding of the Impacts of Climate Change," *PLoS One* (2015) doi.org/10.1371/journal.pone.0140490.

3 Fairtrade Foundation, "Farmers and Workers," accessed at http://www.fairtrade.org.uk/en/farmers-and-workers/coffee.

4 "Climate Change: Pinpointing the World's Most Vulnerable Coffee Zones", World Coffee Research, October 2015., accessed at https://worldcoffeeresearch.org/news/climate-change-wcr-and-leading-coffee-scientists-pinpoint-worlds-most-vulnerable-coffee-zones/

5 International Coffee Organization, "Total Production by All Exporting Countries," January 2017, accessed at http://www.ico.org/prices/po-production.pdf.

6 Peter Laderach, Mark Lundy, Andy Jarvis, Julian Ramirez, Emiliano Perez Portilla, Kathleen Schepp, Anton Eitzinger, "Predicted impact of climate change on coffee supply chains," In: Filho WL, editor, *The Economic, Social and Political Elements of Climate Change,* Climate Change Management; 2011, p. 703–723.

7 Ainhoa Magrach and Jaboury Ghazoul, "Climate and Pest-Driven Geographic Shifts in Global Coffee Production: Implications for Forest Cover, Biodiversity and Carbon Storage," *PLoS One* (2015) 10(7): e0133071, doi: 10.1371/journal.pone.0133071.

8 Laderach et al., "Predicted impact of climate change on coffee supply chains."

9 Henri Myrttinen, "The Complex Ties that Bind: Gendered Agency and Expectations in Conflict and Climate Change-related Migration," Global Policy Volume 8, Supplement 1, February 2017. Accessed at http://onlinelibrary.wiley.com/doi/10.1111/1758-5899.12402/pdf.

10 Peter Baker, "The 'Big Rust': an update on the coffee leaf rust situation," *Coffee & Cocoa International*, January 2014. Accessed at https://www.researchgate.net/profile/Peter_Baker3/publication/274566480_The_Big_Rust_An_update_on_the_coffee_leaf_rust_situation/links/5522b5070cf29dcabb0ed970/The-Big-Rust-An-update-on-the-coffee-leaf-rust-situation.pdf

11 Jacques Avelino, Marco Cristancho, Selena Georgiou, et al., "The coffee rust crises in Colombia and Central America (2008–2013): impacts, plausible causes and proposed solutions," *Food Security* (2015) 7: 303. doi:10.1007/s12571-015-0446-9.

12 2012 wasn't a particularly warm year in Central America, but it was rainy, providing good conditions for the fungus to thrive. The rainy season was interspersed with dry periods, and increased nighttime minimum temperatures kept conditions in the fungus's comfort zone.

13 Avelino et al., "The coffee rust crises in Colombia and Central America (2008–2013): impacts, plausible causes and proposed solutions."

14 Famine Early Warning Systems Network, "Central America Special Report: The impact of the coffee rust outbreak on the coffee sector in Central America," May 2016.

15 Congressional Research Service, "Unaccompanied Alien Children: Potential Factors Contributing to Recent Immigration," R43628 (2014). Accessed at https://fas.org/sgp/crs/homesec/R43628.pdf.

16 Honduras and El Salvador have the two highest murder rates in the world, followed by Guatemala with the 10th-highest. United Nations Office on Drugs and Crime, "Global Study on Homicide 2013: Trends, Contexts, Data," 2014, accessed at https://www.unodc.org/documents/gsh/pdfs/2014_GLOBAL_HOMICIDE_BOOK_web.pdf.

17 Food and Agriculture Organization of the United Nations, "FAO Statistical Pocketbook Coffee 2015," accessed at http://www.fao.org/3/a-i4985e.pdf.

18 Combined total value of green coffee and roasted coffee exports in $USD, divided by GDP in $USD for each year, expressed as a percentage, averaged over 2003-2013, ordered by largest to smallest. Data extracted from the FAOSTAT - The FAO's Food and Agricultural data portal. Coffee trade data accessed at http://www.fao.org/faostat/en/#data/TP, and GDP data from http://www.fao.org/faostat/en/#data/MK.

19 Magrach and Ghazoul, "Climate and Pest-Driven Geographic Shifts in Global Coffee Production: Implications for Forest Cover, Biodiversity and Carbon Storage."

20 Laurence Jassogne, Peter Laderach and Piet van Asten, "The Impact of Climate Change on Coffee in Uganda: Lessons from a case study in the Rwenzori Mountains," Oxfam Research Reports, April 2013.

21 John Magrath, "Turning up the Heat: Climate Change and Poverty in Uganda", Oxfam GB, June 2008. Accessed at http://oxfamilibrary.openrepository.com/oxfam/bitstream/10546/112505/1/turning-up-heat-climate-change-poverty-uganda-170708-en.pdf

22 John Baffes and Anil Onal, "Coffee in Uganda and Vietnam: Why They Performed So Differently," in *African Agricultural Reforms The Role of Consensus and Institutions*, ed M. Ataman Aksoy (Washington DC: The World Bank, 2012), 151-174. Accessed at http://documents.worldbank.org/curated/en/357101468008453119/pdf/699370PUB0Publ067869B09780821395431.pdf#page=173.

23 Armed Conflict Location & Event Data Project, Conflict Trends Report (No. 46), Real-Time Analysis of African Political Violence, March 2016, accessed at http://www.acleddata.com/wp-content/uploads/2016/03/ACLED_Conflict-Trends-Report-No.46-March-2016_pdf.pdf and Conflict Trends Report (No. 47), Real-Time Analysis of African Political Violence, April 2016., accessed at http://www.acleddata.com/wp-content/uploads/2016/04/ACLED_Conflict-Trends-Report-No.47-April-2016_pdf.pdf.

Migration and Displacement in a Changing Climate

Robert McLeman[1]

The physical impacts of climate change are set to become the fastest-growing driver of involuntary migration and displacement globally, beginning in the middle of this century. Climate change is exerting a growing influence on voluntary migration within states and between contiguous countries as households adjust and adapt to shifting local environmental conditions and fluctuations in food and water availability. The greatest concentrations of climate change migrants and displaced people in the future will likely be situated in (1) dryland regions with highly seasonal precipitation regimes, (2) in heavily populated, low-lying coastal areas that regularly experience tropical cyclone activity, and (3) on atolls in the Pacific and Indian oceans (although this is a dynamic that will likely be felt globally). The impacts of climate change on people living in such environments will likely be exacerbated by rapid population growth, declining per capita global food supplies, and growing per capita water scarcity. The large-scale migrations and displacements that emerge may undermine development in the world's poorest countries, swell urban populations to the point that many cities may become ungovernable, erode confidence in government institutions, and undermine peace and stability.

The outcomes just described are not inevitable but grow increasingly likely given the current absence of meaningful international investments to build adaptive capacity. The next 20 to 30 years are a critical period for action. Concerted cooperation among governments, communities, the private sector, and civil society will be needed to change our current trajectory toward a future of disruptive, climate-driven migration.

A snapshot of current global migration

A first step in changing trajectories is to understand why people migrate in the first place.[2] Most people who migrate do so for one or more of the following three reasons. First are economic motivations, with people moving to take advantage of labor market and financial opportunities or to pursue education and training. Sometimes this migration is permanent, other times it isn't. For example, in dryland countries in sub-Saharan Africa, young adults often migrate out of the countryside during the dry season, seeking temporary employment in nearby cities until the rains return and their labor is again needed at home.[3]

Second, various social and cultural incentives, such as family obligations, lifestyle preferences, and societal expectations, contribute to migration. Often, these social and cultural considerations overlap with economic factors. For example, in many dryland and mountainous regions, nomadic and semi-nomadic pastoralism is simultaneously an economic practice and a source of social and cultural identity for those who practice it.[4]

Third, exogenous factors pressure people into migration that they would not otherwise undertake. These include acts of violence, persecution, conflicts, and political instability, as well as natural disasters and government-enforced resettlement to make way for development and infrastructure projects. Involuntary migration for political reasons is currently at its highest level in 20 years, with more than 16 million people currently recognized as requiring refugee protection under the United Nations mandate.[5] Over half of all refugees globally are products of conflicts and political instability in just three countries – Afghanistan, Somalia, and Syria. The number of people displaced by natural disasters varies considerably from one year to the next but is significant; the International Disaster Monitoring Centre reports than since 2008, an average of 26 million people annually have been displaced by disasters.[6]

Migration tends to flow in particular directions; rarely does it take the shape of random movements of people. In less developed countries, most migration takes place within national borders and flows from rural areas and smaller communities to larger cities.[7] Depending on local environmental conditions and land-use practices, there can also be large flows of labor migrants between rural areas. When urban economies contract or collapse, migration can flow from the city to the countryside, although historically this phenomenon has been relatively uncommon, localized, and usually temporary.[8] International migration is less common than intra-national migration, with most international movements taking place between countries that share contiguous borders. The UN Department of Economic and Social Affairs estimates there are currently 220 million people worldwide who have moved out of their respective countries of origin. To put this into perspective, it is estimated there are more than 200 million internal migrants in China alone.[9] Although large-scale, long-distance migration events such as the 2015-2016 movement of more than a million people to Europe from the Middle East and Africa have dominated media and policymaker attention, most international migration to date occurs among less developed countries in the global South.[10]

It is also worth noting an important category of people researchers describe as "rapped populations," that is, people who would migrate out of challenging circumstances but lack the means to do so.[11] Such groups may be found, for example, in locations exposed to natural hazards such as floods and landslides, in highly polluted environments, and in locations with degraded agricultural soils.

Climate change will affect all of the aforementioned types of migration and immobility. Of particular concern is its potential to stimulate larger movements of internal and international migration across a range of geostrategically important regions.

How climate change alters global migration patterns

The preceding snapshot of global migration patterns is set to change in four ways as a result of climate change. First, many regions will experience increasingly severe tropical storms and associated flood events[12] that generate larger volumes of internal displacement and migration. The evidence for this is found by studying the outcomes of extreme storms in recent decades, including Hurricane Mitch (Central America, 1998), Hurricane Katrina (United States, 2005), Cyclone Aila (Bangladesh, 2009) and Typhoon Haiyan (Philippines, 2013). In each case, the storm was followed by a churning pattern of migration as people struggled to recover from damaged housing and lost livelihood assets.

Governments and relief agencies were not able to cope with the scale of homelessness and displacement, leaving many people dependent on extended family networks and informal organizations such as church groups for emergency shelter and support. Large numbers of young adults migrated out of storm-hit areas in search of short-term job opportunities, hoping to remit money home to help rebuild their family's lost or damaged property. This phenomenon shows up, for example, in U.S. immigration statistics in 1999, which reveal a sudden surge in Honduran nationals apprehended entering the country clandestinely via Mexico following Hurricane Mitch (Figure 1).

The likelihood of people returning and resettling in storm-hit areas depends on the extent of damage to housing stocks and basic infrastructure; as seen in Figure 2, the population of New Orleans did not fully recover following Hurricane Katrina. The number of people at risk of displacement by future storms in the Caribbean basin, along the southeastern U.S. Atlantic coast, and in large river deltas of south and southeast Asia will be augmented by rapid population growth in exposed areas, a result of the combined effects of natural population increase and high rates of in-migration and urbanization.[13]

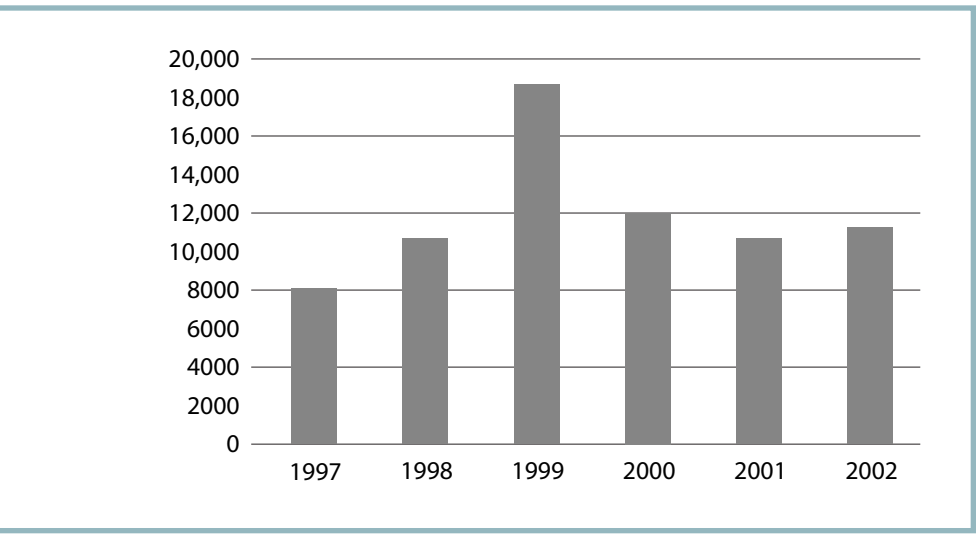


Figure 1: Undocumented Honduran nationals intercepted entering the US from Mexico

Note: Hurricane Mitch struck Honduras in late 1998.

Data source: US INS statistical yearbooks 1998-2003.

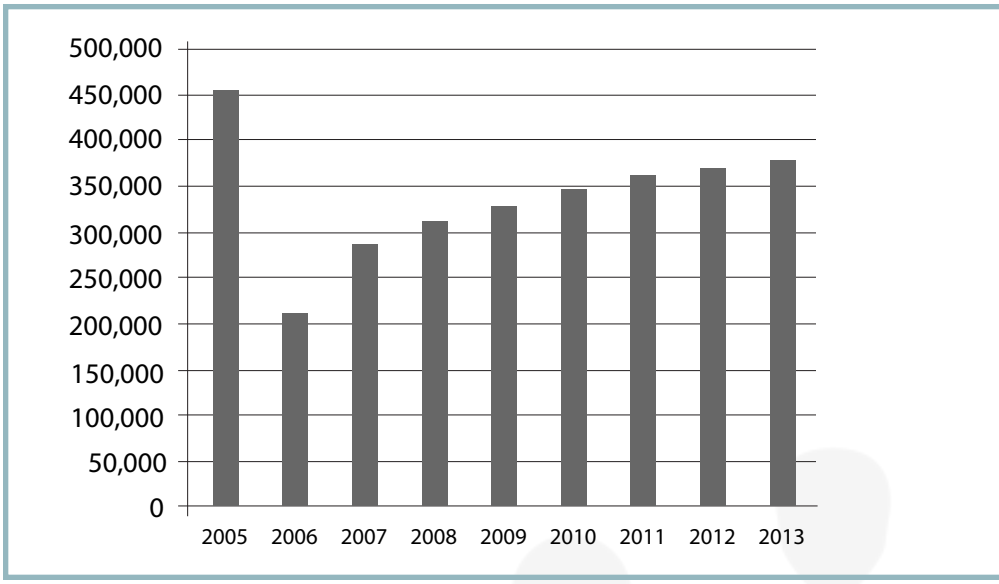


Figure 2: Population of New Orleans before and after Hurricane Katrina, 2005

Data source: US Census

Rising sea levels present an additional set of risks to coastal populations. The current global rate of mean sea level rise (MSLR) is estimated at just over 3mm per year, and appears to have accelerated in recent decades.[14] Scientists warn that if global average temperatures rise by more than 2ºC from pre-industrial levels – as will occur around 2050 if global greenhouse (GHG) emissions continue on current trends – a sea level increase of a half-meter or more by 2100 becomes likely in many parts of the world.[15] While tens of millions of people living in the lowest-lying areas will be threatened with permanent inundation by the end of the century, a more pressing threat is that even modest MSLR facilitates the inland penetration of storm surges and king tides, raising the risks of storm damage to property and the salinization of coastal agricultural lands and groundwater.

Such risks are particularly concerning for populations living on coral atolls in the Indian and Pacific oceans, especially those atolls that are subsiding tectonically or are erosion-prone.[16] In densely populated coastal deltas in Asia, MSLR is exacerbated by the pumping of groundwater, which accelerates the compaction of loosely consolidated sediments. The result is that in places such as Shanghai and the Ganges-Brahmaputra delta, the relative rate of sea level rise is more than double the global average.[17] Wealthier nations will be able to offset such risks by constructing flood barriers and sea walls, such as those that already protect Venice, the Thames estuary, and the Dutch coastline. But less developed nations may be obliged to adopt a strategy of planned relocations from low-lying coastal areas. In the case of atoll nations, there may be no place to retreat to, forcing their populations to seek relocation to other nations.

A third driver of migration and displacement will be changes in regional precipitation patterns, greater dryness in arid and semi-arid regions, and increased frequency and/or severity of droughts. These impacts are expected to be highly variable across and within regions, and climate models do not currently provide reliable, local-scale projections of future precipitation patterns in parts of Asia that experience monsoonal precipitation.[18] The most at-risk regions are those that are simultaneously unstable climatically, are easily susceptible to land degradation, and have disproportionately large rural populations – a description that applies to large dryland areas in South Asia, western China, Sahelian Africa, Central America, and eastern South America.[19] Agricultural productivity will become increasingly erratic, and surface water and ground water resources will decline. A low-end estimate is that 500 million people worldwide will face increased water scarcity by mid-century, the majority living in the aforementioned regions.[20] The already growing rates of migration and urbanization within these regions will accelerate as households and communities adjust and adapt their livelihoods to shifting climatic conditions, causing urban populations to swell.

The fourth way in which climate change will affect future migration patterns is an indirect one: it will place greater stress on food prices. Climate change is expected to have adverse impacts on global agricultural productivity, with knock-on effects on the GDP of less developed nations and on the welfare of the poor.[21] Food production and distribution systems are increasingly interconnected on a global scale, meaning that climate change-related fluctuations in agricultural production in one region stimulate price increases in other regions.[22] The number of people experiencing food insecurity and undernourishment will grow significantly by mid-century because of climate change, with one study estimating an additional 1.7 billion people being in such circumstances.[23]

Short- and long-term migration rates will expand accordingly in less developed countries as households and communities seek to diversify their income sources and stabilize their access to food supplies. Further, wildly oscillating food prices and decreasing household food security can contribute to greater societal instability, urban unrest, and decreasing

confidence in government institutions.[24] This dynamic was witnessed across much of North Africa and the Middle East during the 2011 "Arab Spring" in countries where market structures and high levels of food imports transmit global food-price increases rapidly to households.[25]

Climate change, migration, and conflict

The relationship between climate, migration and conflict is complex and not linear, as shown in recent studies on the role of drought as a factor within the Syrian conflict and subsequent large-scale migration to Turkey and onward to Europe.[26] The direct causes of conflicts cannot be solely attributed to climatic conditions or climate-related scarcity of food, water, or other resources. Rather, climate change adds an additional layer of stress that can increase state fragility and the likelihood of conflict.[27] This happens because adverse climate conditions undermine household livelihoods, heighten socio-economic disparities, and generally serve to increase poverty in affected areas. In this way, the impacts of climate change promote higher rates of population movement, elevate existing social and political tensions between communities, and, therefore, have the overall effect of exacerbating existing conflicts and creating greater potential for new ones.[28] This in turn increases the potential for greater future movements of refugees and forced migrants. However – and this is critical – conflicts and refugee crises do not automatically form in such situations, and the people who flee are typically victims of violence and not perpetrators of it.

States that are already politically fragile are the most likely future epicenters for climate-related violence and forced migration events. Of the 20 highest ranked countries on the Fund for Peace's current *Fragile States Index*, 12 are situated in areas of the Middle East, South Asia, and Sahelian Africa where climate change is expected to create heightened levels of water scarcity, and three – Afghanistan, Somalia, and Syria – currently account for more than half the world's current refugee population (Table 1).[29]

Country	Ranking on 2016 Fragile States Index
Somalia	1
South Sudan	2
Sudan	4 (tie)
Yemen	4 (tie)
Syria	6
Chad	7
Afghanistan	9
Iraq	11
Pakistan	14
Eritrea	18
Niger	19
Kenya	20

Table 1:
Water-scarce countries ranked in the top 20 of the Fragile States Index

Note: Large areas of northern Nigeria (ranked 13th on the FSI) are also at risk of greater water scarcity in coming decades.

Summing up

Climate events and conditions have always had the potential to affect migration and are set to become a dominant influence on regional and global migration in the second half of this century. Epicenters of climate-related migration and displacement will emerge in many locations globally, but especially in densely populated, low-lying coastal areas on most continents, particularly those in tropical cyclone belts; on small island states in the Pacific and Indian Oceans; and in dryland areas in sub-Saharan Africa, the Middle East, South Asia, and western China. The key direct drivers will be increased severity of extreme weather events, rising sea levels, increased precipitation variability and elevated drought risks. The impacts of climate change on global food production and food prices will depress household incomes in less developed nations, which will in turn stimulate increased migration as people seek to diversify their livelihood and income sources. Urban unrest and political stability may also follow, especially in states that already have weak institutions and pre-existing conflicts. Avoiding large-scale involuntary migration and displacement will require concerted and coordinated action to build adaptive capacity and create policies and programs to protect and assist those who are in harm's way.

Notes

1 Wilfrid Laurier University, Waterloo, Canada

2 For a more detailed analysis of how climate affects human migration patterns and behavior, see R.A. McLeman, 2014, Climate and Human Migration: Past Experiences, Future Challenges, New York: Cambridge University Press.

3 D. Rain, D., 1999, Eaters of the dry season: circular labor migration in the West African Sahel, Boulder, Colo.: Westview Press.

4 For example, see H.K. Adriansen, 2008, Understanding pastoral mobility: the case of Senegalese Fulani. The Geographical Journal, 174(3), pp.207–222.

5 Note that the 16 million figure is based on 2015 year-end-statistics, the most recently available at time of writing, and does not include 5 million long-term Palestinian refugees registered with the UNRWA. Source: Accessed at http://www.unhcr.org/statistics/unhcrstats/576408cd7/unhcr-global-trends-2015.html

6 International Displacement Migration Centre statistics, accessed at : http://www.internal-displacement.org/publications/2015/global-estimates-2015-people-displaced-by-disasters/

7 Castles, S. & Miller, M.J., 2009. The age of migration: International population movements in the modern world 3rd ed., New York: The Guilford Press.

8 For example, urban out-migration in Zambia: Potts, D., 2005. Counter-urbanisation on the Zambian Copperbelt? Interpretations and Implications. Urban Studies, 42(4), pp.583–609.

9 UN DESA, 2011. World Population Prospects: the 2010 revision: Highlights and advance tables, New York; Xinhua News Agency, 2011. China's "floating population" exceeds 221 mln. China.org.cn. Available at: http://www.china.org.cn/china/2011-03/01/content_22025827.htm.

10 Nawyn, S.J., 2016. Migration in the Global South: Exploring New Theoretical Territory. International Journal of Sociology, 46(2), pp.81–84.

11 Black, R. et al., 2013. Migration, immobility and displacement outcomes following extreme events. Environmental Science and Policy, 27(S1), pp.S32–S43.

12 Walsh, K.J.E. et al., 2015. Tropical cyclones and climate change. Wiley Interdisciplinary Reviews: Climate Change, 7, pp.65–89.

13 In the US alone, the combined effects of population increase in coastal areas and a modest (90 cm) rise in sea level will place more than 4 million people at risk of flooding by the year 2100; in the absence of population growth, the number at risk would be reduced by half. See Hauer, M.E., Evans, J.M. & Mishra, D.R., 2016. Millions projected to be at risk from sea-level rise in the continental United States. Nature Climate Change, 6, pp.691–695.

14 IPCC, 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge.

15 Hauer, M.E., Evans, J.M. & Mishra, D.R., 2016. Millions projected to be at risk from sea-level rise in the continental United States. Nature Climate Change, 6, pp.691–695.

16 Webb, A.P. & Kench, P.S., 2010. The dynamic response of reef islands to sea-level rise: Evidence from multi-decadal analysis of island change in the Central Pacific. Global and Planetary Change, 72(3), pp.234–246.

17 Brown, S. & Nicholls, R.J., 2015. Subsidence and human influences in mega deltas: The case of the Ganges–Brahmaputra–Meghna. Science of the Total Environment, 527–528, pp.362–374; Day, J.W. et al., 2016. Approaches to defining deltaic sustainability in the 21st century. Estuarine, Coastal and Shelf Science, 183(Part B), pp.275–291.

18 Hijioka, Y. et al., 2014. Asia. In V. R. Barros et al., eds. 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. Cambridge: Cambridge University Press, pp. 1327–1370.

19 Watson, J.E.M., Iwamura, T. & Butt, N., 2013. Mapping vulnerability and conservation adaptation strategies under climate change. Nature Climate Change, 3, pp.989–994; Barbier, E.B. & Hochard, J.P., 2014. Land Degradation, Less Favored Lands and the Rural Poor: A Spatial and Economic Analysis. A Report for the Economics of Land Degradation Initiative., Available at: http://eld-initiative.org/fileadmin/pdf/ELD__Assessment.pdf.

20 Gosling, S.N. & Arnell, N.W., 2016. A global assessment of the impact of climate change on water scarcity. Climatic Change, 134(3), pp.371–385.

21 Calzadilla, A. et al., 2013. Climate change impacts on global agriculture. Climatic Change, 120(1), pp.357–374.

22 Wheeler, T. & von Braun, J., 2013. Climate Change Impacts on Global Food Security. Science, 341, pp.508–513.

23 Dawson, T.P., Perryman, A.H. & Osborne, T.M., 2016. Modelling impacts of climate change on global food security. Climatic Change, 134(3), pp.429–440.

24 Hendrix, C.S. & Haggard, S., 2015. Global food prices, regime type, and urban unrest in the developing world. Journal of Peace Research, 52(2), pp.143–157

25 Ianchovichina, E.I., Loening, J.L. & Wood, C.A., 2014. How Vulnerable are Arab Countries to Global Food Price Shocks? The Journal of Development Studies, 50(9), pp.1302–1319.

26 Kelley, C.P. et al., 2015. Climate change in the Fertile Crescent and implications of the recent Syrian drought. Proceedings of the National Academy of Science, 112(11), pp.3241–3246.

27 Raleigh, C., 2011. The search for safety: The effects of conflict, poverty and ecological influences on migration in the developing world. Global Environmental Change, 21(S1), pp.S82–S93.

28 Brown, O. & McLeman, R., 2009. A Recurring Anarchy?: The emergence of climate change as a threat to international peace and security. Conflict, Security and Development, 9(3), pp.289–305.

29 See http://fsi.fundforpeace.org/

MANAGING SYSTEMIC RISKS

Tools for Understanding Systemic Risks Like Climate Change

Bessma Mourad[1] and Amy Luers[2]

Our world is more interconnected than ever: information and communication technologies have made it easier to connect with people around the world; modern transportation systems have made it simpler and faster for people to move to new locations; and global food systems have enabled the production and trade of crops and staples across hemispheres. While this interconnectedness has brought benefits to many, it also has exposed a new set of complex and systemic risks. Systemic risk can be defined as t "risks imposed by inter-linkages and interdependencies in a system or market, where the failure of a single entity or cluster of entities can cause a cascading failure, which could potentially bankrupt or bring down the entire system or market."[3] The greater the linkages and interdependencies in society and economies, the higher the likelihood that a shock to any one part of a system could lead to unforeseen, cascading consequences that might even trigger the collapse of entire systems.

At the same time, society is facing unprecedented challenges associated with climate change. Climate change is increasing the frequency, severity, duration, and timing of extreme weather events, including heat waves, floods, droughts, and wildfires. Climate-related events can have numerous direct and indirect impacts, including loss of crops, displacement of people, damage to infrastructure, and outbreak of disease. As global economic and social systems are more deeply intertwined, society is more vulnerable and exposed to climate-related disruptions. These disruptions can also lead to systemic risk by affecting supply chains, transportation systems, and trade networks.

There have been significant efforts aimed at understanding place-based and sector-specific climate risks. Climate assessments at local, national, and regional levels are being conducted on an ongoing basis and are designed to consider climate risks to specific geographic locations as well as a range of sectors, including food, energy, water, health, and transportation.[4] However, risks to one sector or to one region, can cascade through networks and across multiple regions. In fact, a study commissioned by the UK government as part of its first national climate change risk assessment found that, "Climate change impacts around the world will multiply existing threats to the UK, and some of these could be an order of magnitude greater than threats from domestic climate impacts."[5] Thus, understanding the breadth of current and future risks – particularly under conditions of climate change and growing inter-dependencies – will be an important component for building resilience of communities, governments, and businesses and for increasing human, national and potentially international security.

Despite the difficulty of assessing climate-related systemic risks, there are a number of tools and methods that can be employed to imagine possible future scenarios, identify patterns and networks, and demonstrate through narratives how climate-related systemic risks might manifest.

Foresight tools and methods: Gaming and Scenario Planning

Serious gaming and scenario planning are foresight tools that have been used by businesses, military, intelligence, and emergency planners to help think creatively about the future, inform strategy, and prepare for risks. These methods can provide a venue to bring together perspectives from across different sectors and aid decision-makers in developing a set of plausible narratives for the future.

- **Serious games** are "games that do not have entertainment, enjoyment, or fun as their primary purpose."[6] These games – based on real or fictionalized situations and contexts – lead participants to make decisions in early stages of the game that will influence both the direction and outcome in the later stages. Such games have long been used by military and intelligence, as part of war gaming, and by city and health planners as part of emergency preparedness simulation efforts. They can be tailored to allow for different degrees of complexity, from the number of actors involved to the geographies included, as well as how far into the future they reach. Outcomes of serious games can help decision-makers test out policies and increase preparedness to a range of possible futures.

- **Scenario planning** was popularized in the early 1970s to help inform decision-making for businesses and is a tool regularly used by the military. Scenario planning is not intended to develop predictions or probabilistic futures, but rather to create plausible narratives for the future. As a professor at

the Wharton School of Business described, "Scenario planning is a disciplined method for imagining possible futures by attempting to capture the richness and range of possibilities, stimulating decision makers to consider changes they would otherwise ignore... Above all, however, scenarios are aimed at challenging the prevailing mind-set."[7] One study that surveyed nearly 80 companies that use scenario planning found that formal strategic foresight efforts add value through (1) an enhanced capacity to perceive change, (2) an enhanced capacity to interpret and respond to change, (3) influence on other actors, and (4) an enhanced capacity for organizational learning."[8]

When trying to understand and anticipate a complex chain of climate-related risks, including human behavior and decision-making, gaming and scenario planning offer complementary ways to integrate multiple perspectives on environmental, social, economic, and political conditions to develop plausible futures that explore potential systemic risks. Examples of where these types of foresight tools have been used for climate risk include:

- In 2015, Lloyds of London commissioned a group of scientists to develop a scenario for an acute but plausible scenario of disruption to global food production. This scenario, published in the report "Food System Shock,"[9] aimed to assist the insurance sector in thinking about the implications of a global food production shock.

- In 2014, the Skoll Global Threats Fund (SGTF) worked with CNA to develop a serious game for South Asia focused on transboundary rivers. Participants from the countries represented – Pakistan, India, Bangladesh, and China – spent two days playing out a game in which decisions on water allocations affected economic productivity, political acceptance, and social stability in the months and years ahead.[10] The game allowed participants to negotiate among different parties and sectors within countries, and among neighboring countries, in an environment simulating many of the existing challenges in the region.

- In 2015, SGTF and the UK's Foreign and Commonwealth Office partnered with CNA to both develop a game and use scenario planning to look at long-term and systemic climate risks over the course of the next century. The game helped to surface a number of trends, including migration, xenophobia, and the rise of nationalist parties months before the events in Europe and the Mediterranean basin unfolded.[11] The experience from this foresight activity contributed to a chapter on systemic risk in the UK's Climate Risk Assessment,[12] released later in the year.

These examples illustrate how foresight tools can be used to actively and creatively engage decision-makers and subject matter experts, test strategy and policies, and surface systemic risks. As demonstrated by various sectors, foresight tools can be a valuable way to explore the broader implications of climate-related risks in an interconnected world. Further enhancing the utility of these approaches are the innovations taking place in the digital age, which may provide additional opportunities for considering climate-related systemic risks.

Digital age: Machine Learning and Collective Intelligence

The digital age has influenced our social, economic, and political systems in countless ways – from enabling rapid communication across continents, to the way in which news is generated and distributed, and even to how social movements are built. Likewise, new technologies have both generated and enabled the collection of an unprecedented amount of information. For example, it is estimated that 2.5 quintillion bytes of data are produced each day (as an illustration, there are 6,000 tweets each second, on average). Remote sensing, crowdsourcing, and big data analysis all allow decision-makers to see changes taking place in the biophysical environment as well as patterns and trends in social, economic, and political systems. Indeed, both machine learning and collective intelligence also could provide opportunities to anticipate climate and systemic risks, both by improving our understanding of those risks and recognizing where and how they emerge.

Machine learning

The unprecedented rate of data generation, storage, and processing power is giving way to the ability to integrate and analyze unstructured and disparate data. For example, advances in machine learning – simply defined as enabling computers to learn from data – enable the processing of large amounts of data and provide insight into interactions and patterns occurring across the globe, including real-time and predictive analytics. The application of machine learning ranges from identifying disease outbreak, to monitoring the potential for mass atrocities, to mapping out illegal wildlife trade. The EMBERS program (short for Early Model Based Recognition using Surrogates) at Virginia Tech has demonstrated the power of publically available open source data to generate predictive analytics about human behaviors. Since launching in 2012, 80-90 % of EMBERS forecasts have been accurate – from protests, to disease outbreaks, to mass migrations.[13]

Yet, the use of machine learning to identify systemic risks from climate change is in its infancy. Hence, the opportunity is ripe for processing large amounts of data to understand the physical dynamics of the planet, identify the interconnections between countries and regions, and surface the attitudes and trends within a society to identify emerging risks from climate shocks.

Collective intelligence

Collective intelligence, also referred to as the wisdom of the crowd, has a long tradition dating back to Aristotle, who said, "When there are many who contribute to the process of deliberation, each can bring his share of goodness and moral prudence… some appreciate one part, some another, and all together appreciate all."[14] Collective intelligence can draw on the insights from across a company, a group of scientists or the general public. As demonstrated by Wikipedia, collective intelligence can also become a source of information, filling the role that encyclopedias once held.

One of the best known experiments using collective intelligence is the Good Judgment Project,[15] which has the aim of "harnessing the wisdom of the crowd to forecast world events." The results have been impressive, albeit surprising. By asking questions on topics including geopolitics and financial markets, the 5,000 volunteers from the general public recruited for the project have been able to better predict international events than U.S. intelligence analysts, including those with access to classified information.[16]

While the Good Judgment Project aims to generate predictions, collective intelligence can be used as a tool to engage with experts, develop ideas, and facilitate collaboration across sectors and geographies. MIT's Center for Collective Intelligence has been a pioneer at exploring how new communications technologies are changing the way people work together around complex climate risks. Its Climate CoLab aims to engage large numbers of people around the world to address climate change through an online platform, while its Resilience Dialogues facilitate conversations between scientists, practitioners, and community leaders to build climate resilient communities.

Drawing on individuals from diverse backgrounds, collective intelligence can facilitate interactions among cross-sector and cross-regional expertise from around the world. Applying this approach to understanding climate-related systemic risks may help decision-makers at local, national, regional and global levels identify where vulnerabilities to those risks may lie, and be better prepared to address or prevent worst-case scenarios. Likewise, innovations in both communications and data technologies can transcend both financial and geographic barriers that may have previously constrained these critical interdisciplinary collaborations.

Conclusion

Despite what appears to be a growing global trend toward inward-facing, nationalist and isolationist beliefs and policies, the world continues to be connected in deeper and more complex ways. Against this backdrop, climate change presents a unique challenge, one in which direct and indirect risks can manifest across borders and through networks. Addressing climate-related risks – particularly in the face of a more interconnected world – will require new approaches and new ways of thinking to

understand, prepare for, and manage these systemic risks. Fortunately, we have tools and methods, some old and others new, that can help decision-makers get ahead of these risks.

Notes

1 Program Officer, Water, Skoll Global Threats Fund

2 Director, Climate Change, Skoll Global Threats Fund

3 Steven L. Schwarcz, "Systemic Risk." Duke Law School Legal Studies Paper No. 163; Georgetown Law Journal, Vol. 97, No. 1, 2008. Accessed at SSRN: https://ssrn.com/abstract=1008326

4 Examples include the U.S. National Climate Assessment, the California Climate Assessment, and the Intergovernmental Panel on Climate Change Assessments.

5 PricewaterhouseCoopers, "International Threats and Opportunities of Climate Change for the UK," June 17, 2013; accessed at http://pwc.blogs.com/files/international-threats-and-opportunities-of-climate-change-to-the-uk.pdf

6 United States Institute for Peace, "Glossary of Terms for Conflict Management and Peacebuilding: Tracks of Diplomacy," United States Institute for Peace, accessed at http://glossary.usip.org/resource/tracks-diplomacy.

7 Paul J.H. Schoemaker, "Scenario Planning: A tool for Strategic Thinking," *MIT Sloan Management Review,* January 15, 1995, accessed at http://sloanreview.mit.edu/article/scenario-planning-a-tool-for-strategic-thinking/

8 Angela Wilkinson and Roland Kupers, "Living in the Futures," *Harvard Business Review*," May 1, 2013, citing study by René Rohrbeck, of Aarhus University, and Jan Oliver Schwarz, of Germany's EBS Business School, accessed at https://hbr.org/2013/05/living-in-the-futures

9 Lloyd's, "Food System Shock: The Insurance Impacts of Acute Disruption to Global Food Supply," Lood's Emerging Risk Report, June 2015, accessed at https://www.lloyds.com/news-and-insight/risk-insight/library/society-and-security/food-system-shock

10 Catherine M. Trentacoste et al., "Bone Dry and Flooding Soon: A regional Water Management Game," Final Report (CNA, October 2014), accessed at https://pdfs.semanticscholar.org/80d4/ec272d699cb49a7a9e6e5acb91b76c4f40a1.pdf

11 Catherine M. Schkoda et al., "Proceedings and Observations from a Climate Risk Event" (CNA, December 2015), accessed at https://www.cna.org/CNA_files/PDF/ICP-2015-U-010942-1REV.pdf

12 David King et al., "Climate Change a Risk Assessment," commissioned by the UK Foreign and Commonwealth Office, 2015, accessed at http://www.csap.cam.ac.uk/projects/climate-change-risk-assessment/

13 Leah Mcgrath Goodman, "The EMBERS Project Can Predict the Future with Twitter," *Newsweek,* March 7, 2015, accessed at http://www.newsweek.com/2015/03/20/embers-project-can-predict-future-twitter-312063.html

14 Cass R. Sunstein and Reid Hastie, "Making Dumb Groups Smarter," *Harvard Business Review*, December 1, 2014, accessed at https://hbr.org/2014/12/making-dumb-groups-smarter

15 The Good Judgment Project was created by Philip Tetlock, Barbara Mellers, and Don Moore and funded by IARPA – the Intelligence Advanced Research Projects Activity

16 Naomi Larsson, "The 'Supers' Who Can Predict the Future: Can We Learn How to See Disaster Coming?" *The Guardian*, March 6, 2017, accessed at https://www.theguardian.com/global-development-professionals-network/2017/mar/06/forewarned-is-forearmed-learning-how-to-predict-the-future

Foresight Tools & Early Warning Systems: Vulnerability Assessments for Abrupt and Non-Linear Climate Risks

Chad M Briggs, PhD[1]

Military and intelligence organizations have been warning about the potential security impacts of climate change since 1990.[2] We have been told that climate change is a "threat multiplier" that can worsen instability in critical areas and trigger natural disasters where we had previously not expected them. Such warnings have been integrated into national intelligence reports, national military strategies, and even training exercises such as war games for policymakers and military officers. Yet at the same time, the public is frequently cautioned that accurate and specific predictions of climate change impacts are not possible, that in complex systems much uncertainty surrounds how climate change may manifest itself at the regional and local levels.[3] In fact, this uncertainty is sometimes used as a rationale for delaying action, for believing we must wait for full information and that otherwise we are simply making "guesses" as to security policy alternatives.[4]

The challenge lies in understanding that not only does uncertainty not preclude action in security risks, but also that uncertainty is, itself, a component of risk that can help guide us in understanding how and where climate change might most severely impact global and regional security the future. Military and intelligence organizations around the world have been increasingly addressing this challenge since the first CNA report was released in 2007, and they have been surprisingly successful in identifying potential climate risks well in advance.[5] This article describes some of the available tools and lessons learned from the field of climate security in the military and intelligence communities, and how to manage systemic risks.

As stated by U.S. flag officers in the first CNA report, National Security and the Threat of Climate Change in 2007, security practitioners do not have the luxury of waiting for full information before making decisions on how to act. To do so would be to invite disaster, as most events are not fully predictable until after they happen. The abilities to predict or anticipate are distinct in crucial ways, and too often they are confused when academic and policy communities are communicating on these issues.

Policymakers and academics/scientists often use evidentiary rules that require high levels of certainty, meaning reducing uncertainty in an attempt to provide clear predictions on cause and effect, and specific future events. The ability to anticipate appears similar but is crucially distinct from prediction. In an anticipatory model, rules and expectations are geared more toward the ability to react given a range of potential conditions, or in bolstering the resilience of a system so that it can withstand sharp external pressures. **To anticipate, therefore, means having foresight into what the future may hold, as distinct from being confident in what will happen.**[6] Military training emphasizes the nature of this future uncertainty. In U.S. Air Force training, for example, pilots must train extensively for a variety of situations that may well never happen, knowing the potentially catastrophic results of not being prepared for even highly improbable events. Likewise, climate security rests on an assumption that changes to the natural environment may result in a variety of potential impacts, and security communities must be prepared to respond to the spectrum, rather than merely choosing those events they feel are most probable.

The data for climate impacts comes from scientists, however, and scientists view uncertainty differently than security planners. Scientists, particularly at universities, are rewarded for publications that demand at least a 95% confidence interval as part of the review process. While security planners might appreciate data with high certainty and confidence, the intelligence community recognized early on that there was a fundamental mismatch between the nature of climate systems and the type of data necessary to conduct effective foresight exercises. The highest climate security risks tend to come from either abrupt shifts in climate systems or in complex combinations of environmental and related factors (such as energy infrastructure). **Both abrupt and complex climate risks required new tools and approaches for translating scientific data into workable security assessments.**

Abrupt climate change refers to the nonlinear behavior of complex systems, where we cannot necessarily expect gradual and linear changes to be the norm. Global climate models can be misleading in this respect, as the global average air temperature suggests a linear (monotonic) relationship between increasing greenhouse gas concentrations and warming of the atmosphere.[7] While this is true over geologically historical periods, this tends to focus too much on air temperature at the expense of other components of the climate system (such as water, precipitation, melting ice, etc), which can

blind us to potentially sudden shifts in critical dynamics of climate systems. These components, such as monsoon rains and ocean currents, can become more unstable before suddenly shifting to a completely different stability level, meaning the West Indian monsoon might simply fail to arrive one year rather than gradually changing over time.[8] Likewise, a combination of smaller changes in environmental conditions can lead to acute impacts. Viewed in isolation, any one of the changes might appear to be easily addressed and not significant, but in combination can overwhelm our ability to respond. Again, the analogy from flight training is in the ability to recognize "improbable combinations of probable events," which are the most common causes of air disasters.[9]

A standard tool to help understand future climate security risks is a vulnerability assessment. Many vulnerability concepts are drawn from the field of ecology, where there is an understanding that risks are more complex than a simple formulation of impact x probability. Certain parts of ecological systems are more exposed to outside hazards, more sensitive to their pressures, less resilient, or so vital that their failure can lead to collapse of the larger system (e.g. "keystone species"). Similar concepts are used in field epidemiology, in helping to determine which populations are most in need of study and monitoring, recognizing that vulnerable populations take highest priority. In climate security, vulnerability assessments can be scaled from continent-wide efforts at examining risks to Africa, to community-level studies of environmental pressures and refugees. The common theme of vulnerability assessments is to help identify so-called "hotspots" where security risks may be experienced first, and so help direct policymakers to make plans for mitigation or adaptation.[10]

Vulnerability assessments come in a variety of different forms, depending upon the scale and focus of the assessment, and assumptions concerning how the climate or impacted systems work. A common challenge, however, is how to downscale global climate processes into regional or local impacts, and then identify where climate impacts in one region may pose security risks to another. While the methodological hurdles of downscaling from global climate models to regional climate models is explored at length elsewhere[11], it should be kept in mind that certain regions do not have high-resolution climate projections on a small scale, and that this uncertainty is generally multiplied by uncertainties on the ground concerning lack of monitoring, political instability, questionable economic reporting, and non-climate environmental changes (such as illegal logging). At times the climate changes can be predicted with fairly high confidence, such as projected sea level rise and subsequent flooding of land in Bangladesh. The responses of Bangladeshis, however, or security impacts beyond the community and state level, simply cannot be predicted in advance.

Likewise, most climate models for temperature and precipitation predict that European countries on the Mediterranean will shift to desert conditions similar to those of North Africa by the end of the 21st century.[12] Given how even short-term predictions on politics in Europe are extremely difficult, identifying security risks over such a long time period is nearly impossible. These challenges lead many vulnerability assessments to focus on shorter-term and most probable outcomes, which while useful in and of themselves, can lead to blind spots in long-term planning for climate and security risk resilience. Depending on their methodologies, vulnerability assessments may also have difficulties with assessing risks of abrupt climate changes, as these non-linear events are difficult to predict with any accuracy.[13]

The second tool for climate security is the development of so-called "dark reports." The idea of dark reports is to identify what is not yet known about the subject, why it is not known, and communicate these findings to help planners anticipate potential risks associated with this uncertainty. While common practice among military and intelligence communities, scientists are often discouraged from publishing negative findings, or from communicating uncertainties to policymakers who keep pressing for accurate predictions. Yet it is necessary to map out uncertainties in order to place existing knowledge within a larger context.[14] As an example, when the IPCC fourth assessment was released in 2007, very little mention was made in the report of potential abrupt melting of the Greenland ice sheet. Although cryologists knew of this possibility and were increasingly concerned over emerging data, the structure of the IPCC placed priority on publishing only high-confidence projections. Because of he lengthy review process, that meant much of the observational data was at least 4 to 5 years old by the time of publication. This uncertainty over ice sheet modeling meant that no warning was communicated to policymakers, who then interpreted lack of evidence as evidence of no risk.[15] Very soon after publication, however, new findings on accelerated ice melt in Greenland came as a surprise to both journalists and policymakers. As many climate scientists were aware of this "known unknown" the incident suggested the need for the intelligence community to engage more meaningfully with the scientific community.

The next early warning tool to emerge was, therefore, a new approach to open-source intelligence in cooperation with climate and environmental scientists. Early efforts in climate security recognized the mismatch between standards of evidence in the scientific and intelligence communities. While natural scientists possessed an immense amount of information concerning potential risks of abrupt climate changes and impacts, universities and academies strongly discourage information-sharing of uncertain concepts. Likewise, standard rules for secrecy within the intelligence and military communities dictate that the standard model for open-source intelligence (OSINT) is collection of peer-reviewed articles, with no communication or cooperation back to the scientists. This OSINT model was insufficient, as scientists were necessary

for explaining the nature of the research and wished to shepherd their data rather than merely handing it over to faceless individuals.[16] New forms of unclassified information sharing were developed under the U.S. Department of Energy and U.S. Air Force, including U.S. Department of Defense research programs under the Minerva Initiative. Scientists, although often not rewarded by their universities for doing so, were encouraged to participate in the formation of new climate security scenarios, where the emphasis was on *plausible* futures rather than the most probable ones. This information sharing was also extended to war games. For example, in 2011 NASA scientists cooperated with the U.S. Air Force on integrating volcanic ash data into traditional military scenarios. In subsequent years, scientists helped to refine Air Force scenarios on tropical storm and tsunami impacts to the Hawaiian Islands.[17]

It should be noted that the new approach to open source intelligence was necessary due to the often ignored distinction between open source information and open access information. Simply because information is unclassified does not mean that security planners actually have access to such information. At times articles can begin behind journal and publication paywalls or the information may be known to experts who only share this knowledge when they can trust that it will be used properly. Likewise, scientists by their training are skeptical of accepting risk models and conclusions without knowing the source of information or how certain assumptions were arrived at. Experience in both the U.S. and Swedish governments in creating climate security scenarios suggested scientists would often push back against scenarios that had been "black-boxed," meaning created by outside experts then simply presented to the public, and that the best way to overcome such reluctance was to involve those same scientists in the creation of the scenarios in the first place.[18]

Scenario creation exercises by communities of experts became a useful tool for assisting the military and intelligence communities, both in fostering cooperation among nonsecurity experts, and in developing unique scenarios that would not previously have been possible. The open-source scenarios brought together diverse collections of experts in environmental, energy, security, engineering, and social/political fields. Given semi-random background components from the fields of energy and environmental security, facilitators led small groups through the creation of potential future events. By creating unlikely combinations of environmental "drivers," within only a few hours groups were often able to create scenarios that had previously not been considered, including identification of key vulnerabilities, critical uncertainties, and "tripwire" events, allowing interpretation of otherwise weak signals into their importance for possible future risks.

For example, an unpublished scenario developed by the U.S. Department of Energy (DOE) in 2009 examined a potential future of commercial, undersea mining of methane (CH4) clathrate deposits. With the east coast of Japan as the focus region, the

scenario looked at developing technologies and their interaction with environmental systems. However, the more important lesson to emerge from the scenario related to the vulnerability of Japanese energy systems to external shocks - information that proved to be useful preparation for the Fukushima nuclear accident in 2011. Also in 2009, DOE began mapping potential impacts from tropical storms in the New York City region, highlighting transport and energy vulnerabilities well in advance of Hurricane Sandy in 2012.[19] The same approach was used by the U.S. Air Force in 2012 to help engage both military and civilian planners on the rising threats of tropical storms to the Hawaiian islands. The scenarios highlighted island vulnerability of energy and food imports, and allowed military planners to assist civilians in understanding the potential future risks they faced. The Hawaiian scenarios relied upon input from local scientists who described potential abrupt changes from shifts in ocean currents, warnings that in more recent years appear to have become accurate.[20]

In these examples, which are far from comprehensive descriptions of tools available for climate security foresight, it is worth emphasizing that the ability to anticipate potential future events relies upon expertise beyond what is available in one office or department. The complexity of climate security requires effective engagement with scientists, military planners, intelligence analysts, and, crucially, local experts who can give resolution to specific impacts and vulnerabilities. While this engagement often runs counter to the secrecy of security communities, or the publishing demands of academia, it is critical for the ability to understand the broad spectrum of climate security risks, and where the impacts may first be felt.

Notes

1 Principal, GlobalInt LLC

2 See Climate Security 101 Project, Climate Security Chronology, accessed at https://climatesecurity101.org/chronology/

3 Daniel E. Schindler and Ray Hilborn. "Prediction, precaution, and policy under global change," Science 347, no. 6225 (2015): 953-954.

4 Juliet Roper, Shiv Ganesh, and Theodore E. Zorn. "Doubt, Delay, and Discourse: Skeptics' Strategies to Politicize Climate Change," Science Communication 38, no. 6 (2016): 776-799.

5 CNA Corporation. *National security and the threat of climate change*. Alexandria: CNA Corporation. April 2007.

6 Walter L. Christman, Frank C. DiGiovanni, and Linton Wells II. "Defense Horizons." (2015). Accessed at http://ndupress.ndu.edu/Portals/68/Documents/defensehorizon/DH-80.pdf

7 Richard B. Alley, Jochem Marotzke, William D. Nordhaus, Jonathan T. Overpeck, Dorothy M. Peteet, Roger A. Pielke, R. T. Pierrehumbert et al. "Abrupt climate change." science 299, no. 5615 (2003): 2005-2010.

8 M. Berkelhammer, A. Sinha, L. Stott, H. Cheng, F. S. R. Pausata, and K. Yoshimura. "An abrupt shift in the Indian monsoon 4000 years ago," Climates, landscapes, and civilizations (2013): 75-88.

9 Karl E. Weick, "The vulnerable system: An analysis of the Tenerife air disaster," Journal of management 16, no. 3 (1990): 571-593.

10 Joshua W. Busby, Todd G. Smith, Kaiba L. White, and Shawn M. Strange. "Locating climate insecurity: Where are the most vulnerable places in Africa?"; Climate change, human security and violent conflict, pp. 463-511. Springer Berlin Heidelberg, 2012.

11 Frans Berkhout, Bart van den Hurk, Janette Bessembinder, Joop de Boer, Bram Bregman, and Michiel van Drunen. "Framing climate uncertainty: socio-economic and climate scenarios in vulnerability and adaptation assessments," Regional environmental change 14, no. 3 (2014): 879-893.

12 Sergio M. Vicente-Serrano, Juan-I. Lopez-Moreno, Santiago Beguería, Jorge Lorenzo-Lacruz, Arturo Sanchez-Lorenzo, José M. García-Ruiz, Cesar Azorin-Molina et al. "Evidence of increasing drought severity caused by temperature rise in southern Europe," Environmental Research Letters 9, no. 4 (2014): 044001.

13 Timothy M. Lenton and Juan-Carlos Ciscar. "Integrating tipping points into climate impact assessments," Climatic Change 117, no. 3 (2013): 585-597.

14 For further explanation see: Chad M. Briggs, "Developing strategic and operational environmental intelligence capabilities," Intelligence and National Security 27, no. 5 (2012): 653-668.

15 Personal communication with Richard Alley, July 3, 2009.

16 Chris Pallaris and Sean S. Costigan. "Knowledge ecologies in international affairs: a new paradigm for dialog and collaboration" (2010). Accessed at https://pdfs.semanticscholar.org/30bf/e4c84db73722004a675e370d11f70bd91217.pdf

17 This was a collaboration between the USAF Wargaming Institute, NASA/JPL (specifically, David Pieri), and USAF Minerva.

18 Henrik Carlsen, Karl Henrik Dreborg, and Per Wikman-Svahn. "Tailor-made scenario planning for local adaptation to climate change," Mitigation and Adaptation Strategies for Global Change 18, no. 8 (2013): 1239-1255.

19 Chad M. Briggs, "Environmental change, strategic foresight, and impacts on military power," Parameters 40, no. 3 (2010): 1.

20 Andrew Freedman, "Hawaii at Growing Risk of Hurricanes, Studies Show," Climate Central, May 8, 2013, accessed at http://www.climatecentral.org/news/hawaii-at-risk-for-more-hurricanes-studies-show-15966.

Mapping Epicenters of Climate and Security Vulnerabilities[1]

Joshua Busby[2]

Understanding where the worst effects of climate change could come to pass and what that means for security is an important issue for policy-makers. Research on potential climate security "hot spots" can inform priorities for foreign assistance, disaster preparedness, and efforts by intelligence and security agencies to anticipate where future missions might be needed.[3] Mapping climate security vulnerability is one tool that researchers and policy-makers can use to better understand and prepare for these risks.

The basic goal of vulnerability mapping is to provide decision-makers with a visually intuitive snapshot of likely priority areas in the short- to medium-term. Vulnerability mapping first requires an understanding of what is meant by vulnerability. Vulnerability to what and for whom? Many climate vulnerability studies focus on threats to livelihoods, while much of the climate security literature focuses exclusively on conflict. Mapping vulnerability can also be conducted by emphasizing the risks of large-scale loss of life, including but not limited to conflict.

Significance of Mapping to Policy

An increasing number of government agencies and nations have demonstrated an active interest in climate change as it relates to security and foreign policy priorities. Although uncertainty remains as to how exactly impacts of climate change will manifest, there is widespread recognition that climate change magnifies existing problems and adds additional stressors to already fragile situations. Environmental factors are being considered for inclusion in early warning systems and assessments of state fragility. Policy-makers generally agree that a major investment in data collection

and the improvement of early warning systems is needed. Integrating climate change in policy decisions requires understanding complex social interactions and incorporating information from both the natural and social sciences. Policy-makers face the challenge of how to utilize research and analysis for developing sound policies, especially if different mapping efforts produce discordant results.

Maps and indices should provide a clear presentation of research findings and their assumptions while not overstating the case or allowing audiences to take away the wrong message. A single composite map of vulnerability mapping often has many uncertainties that are hard to convey on the map itself. Despite the challenges of creating and using maps, they can provide an important starting point for a dialogue between research and policy-makers. That said, maps on their own may provide insufficient guidance to policy-makers. What is mapped largely depends on what is of interest. Different audiences are likely to need different maps.[4] The critical factor is for map-makers to be transparent about their choices and for policy audiences to be critical consumers of whatever maps are put before them.

Challenges of Mapping Vulnerability

Vulnerability is often understood be a combination of different factors, including physical exposure, sensitivity, and adaptive capacity.[5] Indicators that can be used to define vulnerability include physical exposure, population, household resilience, and governance. One challenge is that indicators are not always available at the same spatial resolution. Depending on the purpose of the mapping exercise, indicators can be aggregated up to the national level. In other mapping projects, some of the sub-national differences are retained. Global maps often use national level data to compare country-level differences. Regional maps might use more fine-grained data to show sub-national differences within and between countries. More fine-grained data might be available, depending on the region, for more local-scale mapping exercises.

Data can also be combined in different ways for display on a map. Indicators can be overlaid one atop the other. Indicators can be transformed into a common scale and added together, multiplied, or in some combination of different weights. When the maps are displayed, the colors can be stretched on a continuum or divided into different discrete colors based on how the data are distributed and how many colors the map-maker wants to show. Those choices can have major implications for what the final patterns look like. The different indicators chosen and the scale in which they are shown will ultimately paint different pictures of vulnerability that can be tailor made according to the needs of the policy-makers.

Case Study on Mapping Climate Security Vulnerabilities for Policy-Makers

From 2009 to 2016, the Strauss Center research group developed multiple iterations climate security vulnerability maps at the sub-national level for Africa and for 11 countries in South and Southeast Asia. The Department of Defense's Minerva Initiative financed both the Climate Change and African Political Stability (CCAPS)[6] and the Complex Emergencies and Political Stability in Asia (CEPSA) projects,[7] and a wider research group completed a project for USAID, mapping the intersection of global exposure to climate-related hazards and state fragility.[8]

Climate Security Vulnerability

Both the CCAPS and CEPSA projects map subnational climate change vulnerability to identify the locations of likely chronic vulnerability. Both models have an explicit security focus, emphasizing situations where large numbers of people could be at risk of death from exposure to climate-related hazards and the follow-on consequences that could result from inadequate responses to climate shocks, including political instability and violent conflict.

While the projects explore conflicts affected by climate processes, the research has a stronger emphasis on humanitarian emergencies and disasters because the mobilization of militaries for cyclone relief, floods, famine, and other climate-related phenomena is seen as the most immediate and consistently pressing challenge. These maps focus on internal threats within states, but it is worth noting that many environmental phenomena traverse borders and have trans-border security implications.[9]

The Logic and the Method

In the model, vulnerability is seen as driven by a concatenation of four processes, or what are called "baskets," including (1) physical exposure to climate hazards, (2) population density, (3) household and community resilience, and (4) governance.

The logic is as follows: You cannot have climate vulnerability without physical exposure to climate hazards, but large numbers of people cannot die if a place is unpopulated or only lightly populated. Even in populated areas, some communities are more resilient than others. The first line of defense is the resources and capabilities communities possess. All else equal, better educated and healthier populations will likely fare better. However, some hazards may exceed the capacity of local communities to respond. Whether governments are willing and able to help them in times of need will affect how deadly and destabilizing climate exposure events are.

Each of the baskets, save population density, is composed of multiple indicators. For example, the physical exposure basket includes historic data on cyclones, wildfires, floods, two indicators related to water scarcity, and low-elevation coastal zones subject to storm surge and sea-level rise. Indicators were selected at the finest spatial resolution possible, with the physical exposure and population baskets having fine-grained spatial resolution and the last two baskets consisting of provincial or national-level data.

The data is normalized on a common scale and then added together to make a composite index, and thus provides a snapshot of the places likely subject to chronic climate security vulnerability.

How To Use The Maps

There is a final report[10] and an on-line climate dashboard for the completed CCAPS project[11] and an initial dashboard for the CEPSA project.[12] Both climate dashboards include a model-building process with the final composite map and basket maps.

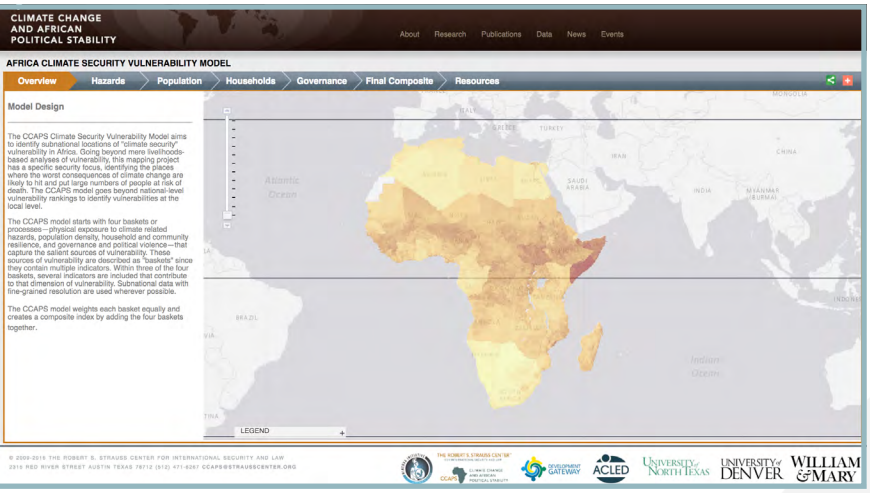


Figure 1: Screenshot of CCAPS Climate Vulnerability Dashboard

Here is a CCAPS composite map for Africa. The model shows extensive vulnerability across the Horn of Africa (particularly in Somalia and to a lesser extent Ethiopia), South Sudan, in pockets around the Great Lakes, with higher areas of vulnerability throughout northern Nigeria and southern Niger, as well as West Africa in Guinea and Sierra Leone and coastal Mozambique.[13]

Here is a composite map for Asia. The current iteration of the model shows much of Bangladesh, parts of southern Myanmar – the Ayeyarwady region – and parts of southern and northwest Pakistan – Sindh and Khyber Pakhtunkhwa – as the most vulnerable.[14]

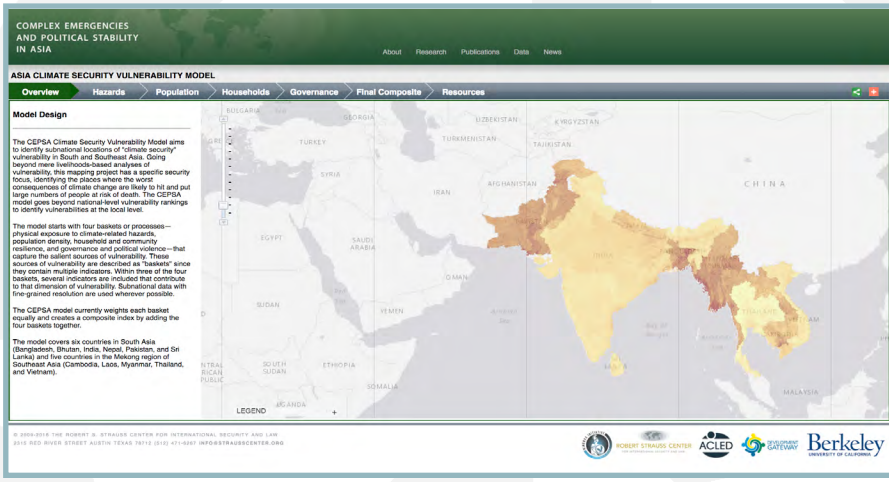


Figure 2: Screenshot of CEPSA Climate Vulnerability Dashboard for Asia

The maps show the position of the places relative to all of the other places in the study area. According to the composite map, Somalia is vulnerable relative to the rest of the continent of Africa, and Myanmar is more vulnerable relative to the rest of the countries in South and Southeast Asia.

The online dashboard maps also allow viewers to zoom in to areas of interest to get a more fine-grained picture of specific places and how those locations compare to the rest of the region.

However, map patterns should not be directly compared to each other, as the data are scaled relative to their regions. Forthcoming USAID work will allow the comparison of the relative exposure of different places at the global level, but that is only measuring physical exposure to climate risks.

These dashboards are part of wider projects that look at patterns of foreign aid and conflict. The CCAPSs maps include a set of additional layers that can be placed on top of the base layer of climate vulnerability, including aid, SCAD and ACLED conflict events, and constitutional design.

In the CCAPS project, the team analyzed where World Bank and African Development Bank projects were distributed to see if that corresponded with patterns of climate vulnerability (see Figure 3).[15]

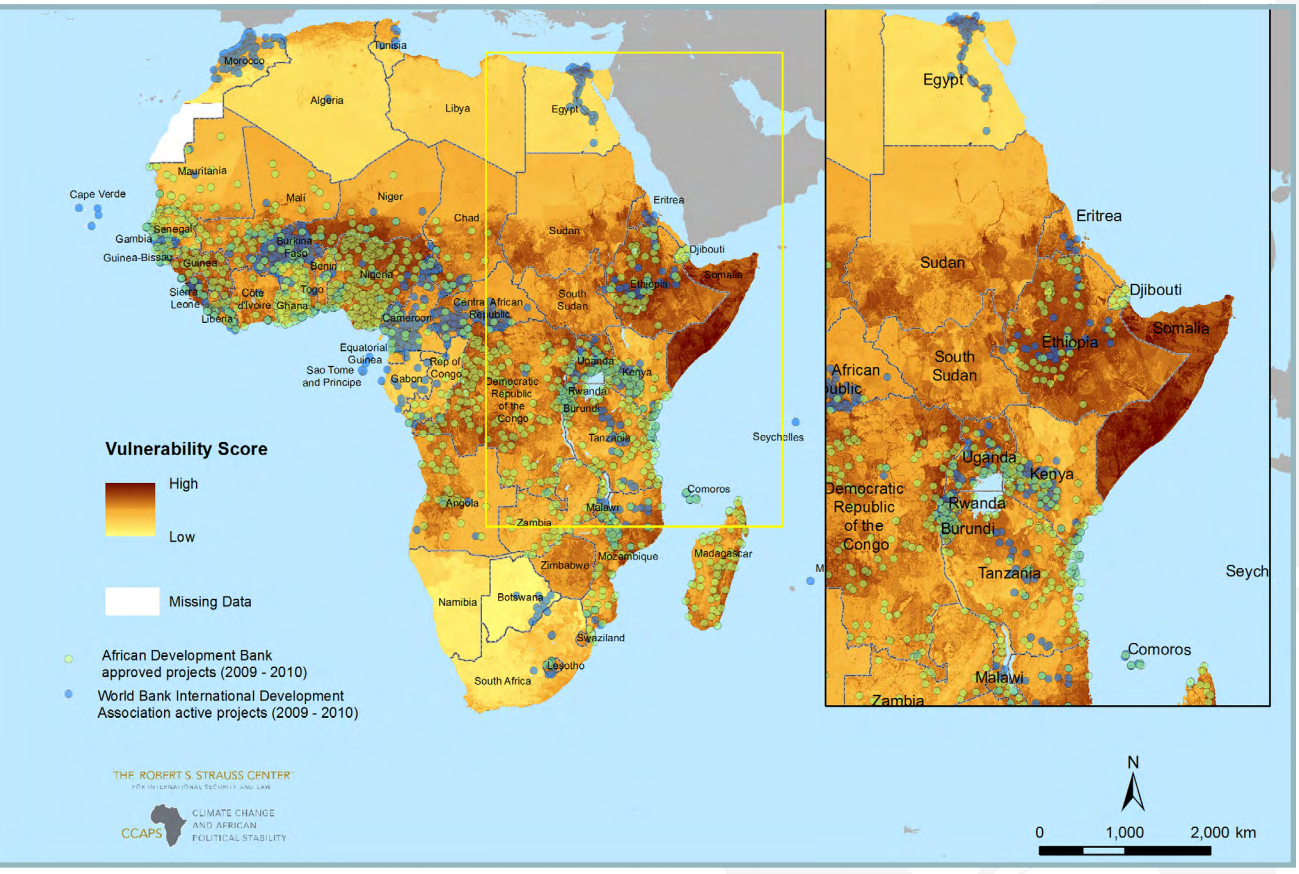


Figure 3: World Bank and African Development Projects 2009-2010 and Climate Security Vulnerability

The dashboard maps where climate-related projects from the World Bank were located from the period 2008 to 2012 (see Figure 4). What is notable for both wider development projects and specific climate projects is that vulnerable countries such as Somalia did not receive aid. The absence of a functioning government foreclosed the possibility of spending money there.

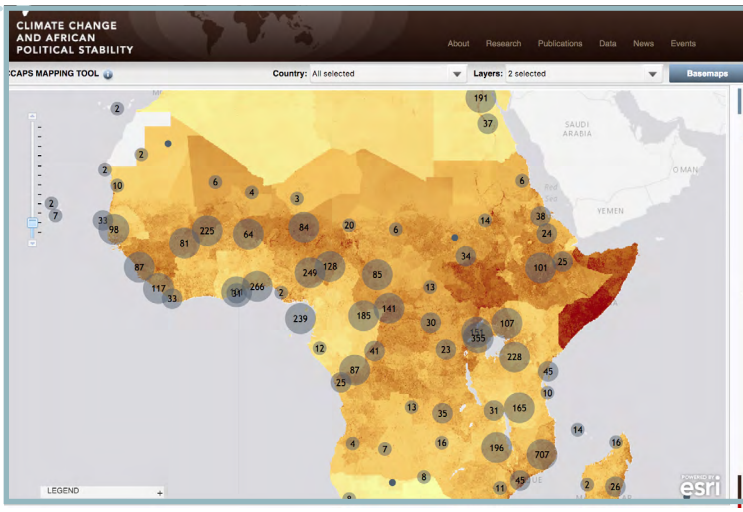


FIGURE 4: Screenshot of World Bank Climate-Related Aid Projects and Vulnerability

The forthcoming CEPSA dashboard will allow for overlaying conflict, disaster response, aid data, as well as related external datasets, including the ability to import layers from ArcGIS Online and to design and compare maps.[16]

MAPS AS POINTS OF DEPARTURE

Maps are seductive. They simplify a complex reality. However, if one embraces these maps as "the truth" without questioning their accuracy or their assumptions, this could lead to bad policy choices.

For that reason, these maps are points of departure for further conversation and investigation, including consultation with local experts, comparison with other data sources, and qualitative assessments.

For example, do the patterns of at-risk areas correspond with what we know about the geography of past climate-related disasters or conflict sites? Somalia faced two drought-related famines in the last 20 years, in the early 1990s and again in 2011, with an unfolding famine risk in 2017. Myanmar experienced some of the largest losses in recent memory when 140,000 died after the 2008 Cyclone Nargis.

While that provides some support for the maps, one can do this more systematically by ground-truthing the maps in the field as well as through sensitivity analysis and examining alternative ways of presenting and aggregating the data. Findings can also be compared with data collected by others.

For example, if one looks at the areas facing high climate security vulnerability in the CEPSA model through the perspective of numbers of people or proportion of the population exposed, the vulnerability in India and Vietnam is elevated and Bangladesh remains among the most vulnerable. All three have large numbers of people and/or high proportions of their populace facing high vulnerability.

Comparing Results

One can also compare the CCAPS and CEPSA model results with the geographic patterns of climate-related disasters. To do this, the research team geo-referenced climate-related disasters in the EM-DAT International Disaster Database for Africa and Asia. One can look at this in terms of the number of events, the number of people killed, and the number of people affected. In Asia, these patterns present different patterns than the CEPSA composite map (see Figure 5 for number of events). Are these EM-DAT-based maps, therefore, a more accurate depiction of an underlying reality compared to the CEPSA maps? EM-DAT data on casualties are not very precise and rely on reporting from aid groups and others, but the purpose of such comparisons is not to provide definitive answers but to stress-test the model to see how consistent the patterns are across different data sources and approaches.

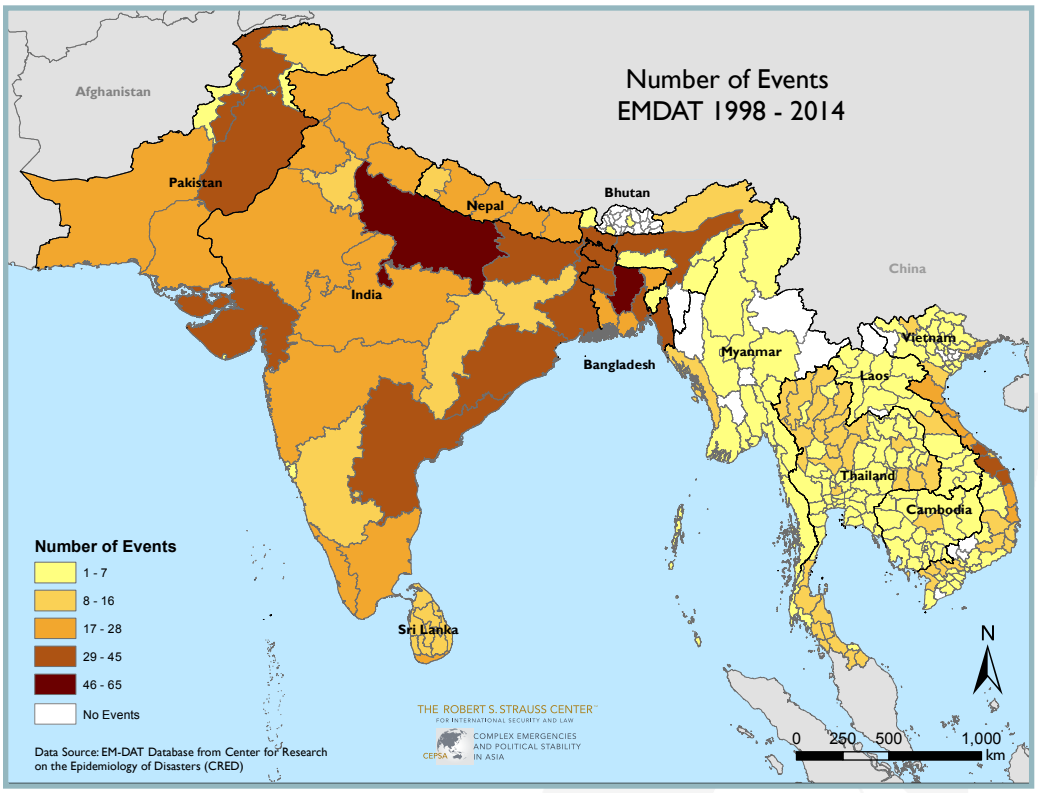


Figure 5: Climate Disaster Events in South and Southeast Asia

The CCAPS and CEPSA maps are based on historic data on physical exposure to climate hazards, not future climate change risk. In collaborative work with climate scientists on Africa, the research team assessed how future hazards are likely to be distributed, namely the number of dry days, heavy-rainfall days, and heat-wave events by the middle of the 21st century.[17] For example, the team mapped the difference in dry days – defined as 21-day periods with less than 1 mm of rainfall – between modeled results for the late 20th century and the mid-21st century. The difference map below shows parts of the Sahel are projected to become wetter (in blue below in Figure 6) while much of southern Africa will experience more dry days (in red below).[18]

Composite Vulnerability and Strategic Significance

Another consideration is how these findings intersect with the relative strategic importance of different country contexts. Decision-makers bring their own assumptions about what places are strategically significant, but one can surface these assumptions by identifying potential indicators of strategic importance and overlaying these on the vulnerability maps, such as piracy attacks, terrorism, oil reserves, critically important minerals, and embassies. The map below shows the patterns for piracy attacks and climate vulnerability in Africa, which reveal the historic high incidence of piracy attacks off the Gulf of Aden. Such maps tell us nothing about whether climate vulnerability and piracy are causally related, merely that there are locations of overlapping risk, given historic data (see Figure 7).

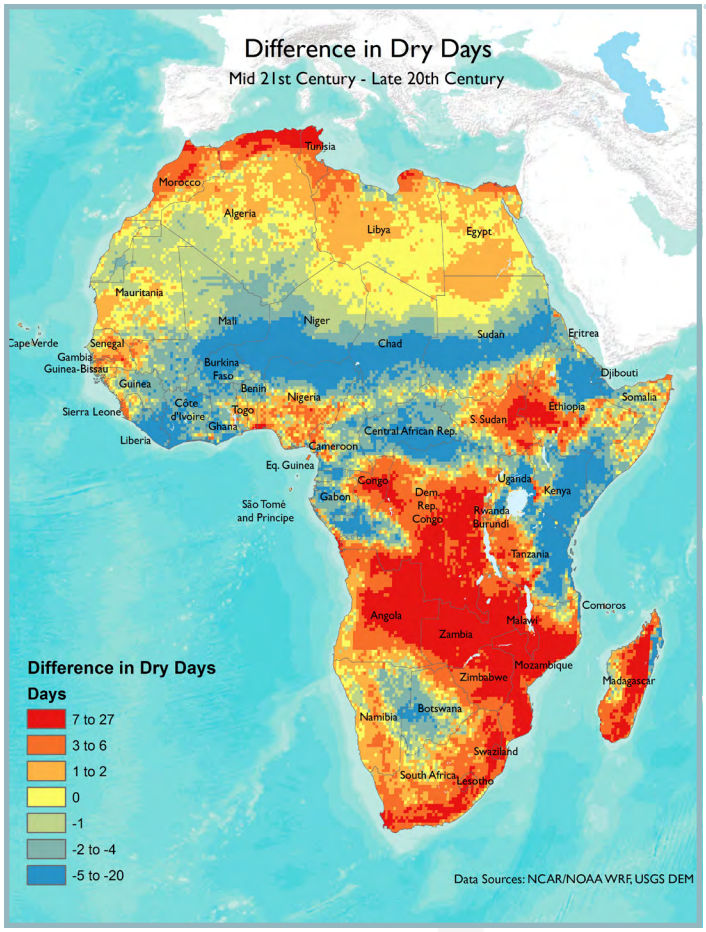


Figure 6:
Projected Difference in Dry Days for Africa from Late 20th Century to Mid-21st Century

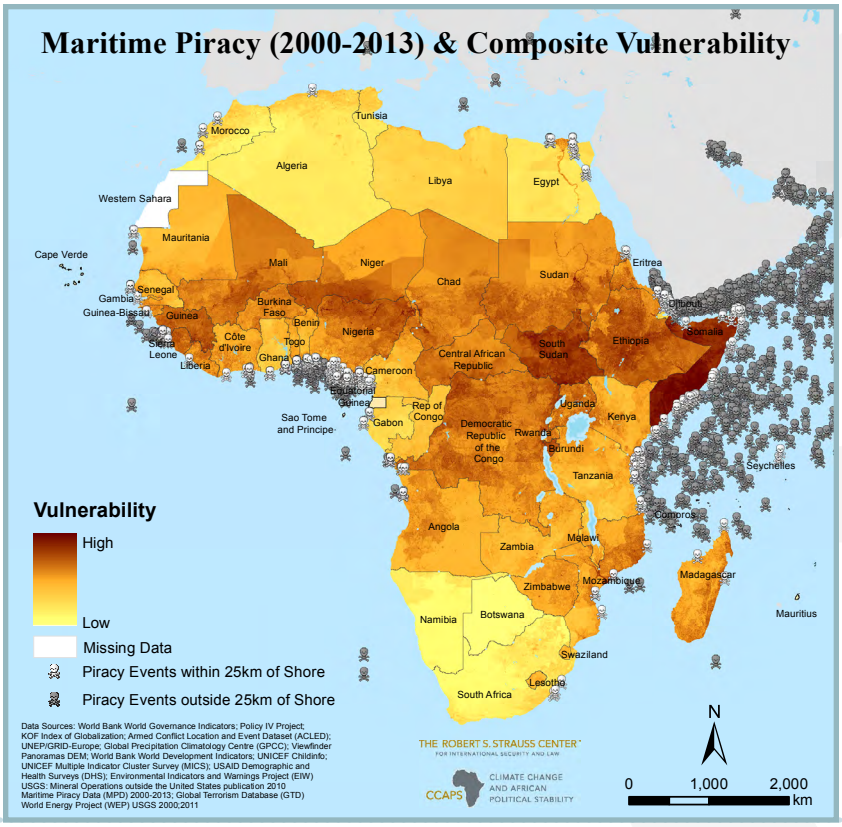


Figure 7:
Piracy Attacks and Climate Vulnerability

Beyond Mapping

These maps are a point of departure for a conversation about climate security vulnerabilities in different regions.

While the past might tell us something about the short-run, future climate change may shift the geographic patterns of exposure and produce climate effects of a magnitude the world has not seen in the recent historical record.

Moreover, these maps are meant to tell a story about chronic places of concern. Different kinds of maps can serve different purposes. The policy community, for example, is often interested in emergent risks for early warning. Programs such as the Famine Early Warning Systems Networks (FEWSNET),[19] are critical for this effort. More geographically comprehensive seasonal forecasts of water scarcity and overall water balances are also available from the consultancies such as ISciences.[20]

Even if we agree that these maps reflect an underlying reality, the policy implications are not straightforward. Should Somalia receive more climate-related aid compared to its peers because of its vulnerability? Or, is it viable to spend aid money in Somalia, given weak governance and the violent threat of al Shabaab? If one examines the last 20-year record more carefully, there were four major drought episodes in Somalia. Only two of them ended in drought. Why is that? Both Ethiopia and Somalia faced major climate shocks in recent years. In Somalia's case, the drought ended in famine while Ethiopia fared better. Why is that? These are the kinds of questions that the maps can't answer, but they can start to point us in the right direction as to how to answer them.

Notes

1 This material is based upon work supported by, or in part by, the U.S. Army Research Laboratory and the U. S. Army Research Office via the U.S. Department of Defense's Minerva Initiative under grant numbers W911NF-09-10077 and W911NF-14-1-0528.

2 LBJ School of Public Affairs, University of Texas-Austin busbyj@utexas.edu

3 Joshua W. Busby et al., "Climate Change and Insecurity: Mapping Vulnerability in Africa," *International Security* 37, no. 4 (2013): 132–72; Alex de Sherbinin, "Climate Change Hotspots Mapping: What Have We Learned?," *Climatic Change* 123, no. 1 (March 1, 2014): 23–37, doi:10.1007/s10584-013-0900-7.

4 For a discussion of these issues, see Joshua W. Busby and Jennifer Hazen, "Mapping and Modeling Climate Security Vulnerability: Workshop Report" (Austin, Texas: Strauss Center for International Security and Law, October 2011), https://www.strausscenter.org/climate-vulnerability-publications?download=47:mapping-and-modeling-climate-security-vulnerability-workshop-report.

5 IPCC Working Group II Report, "Climate Change 2014: Impacts, Adaptation, and Vulnerability" (IPCC, 2014), http://ipcc-wg2.gov/AR5/.

6 See https://www.strausscenter.org/ccaps

7 See https://www.strausscenter.org/cepsa/

8 Ashley Moran et al., "The Intersection of Global Climate and Security Risks" (Washington, D.C.: USAID, Forthcoming 2017).

9 For an exploration of some implications associated with transboundary water management, see Joshua Busby, "Water and U.S. National Security" (Council on Foreign Relations, 2017), http://www.cfr.org/water-security/water-us-national-security/p38677.

10 CCAPS, "CCAPS Final Program Report on 'Climate, Conflict, and Governance in Africa'" (Strauss Center for International Security and Law, November 2016), accessed at https://www.strausscenter.org/ccaps-news/ccaps-final-program-report-on-climate-conflict-and-governance-in-africa.html.

11 Accessed at http://ccaps.developmentgateway.org/buildingthemodel

12 Accessed at http://cepsa.developmentgateway.org/buildingthemodel

13 These results are discussed in Joshua W. Busby, Todd G. Smith, and Nisha Krishnan, "Climate Security Vulnerability in Africa Mapping 3.0," *Political Geography,* Special Issue: Climate Change and Conflict, 43 (November 2014): 51–67, doi:10.1016/j.polgeo.2014.10.005.

14 Joshua W. Busby et al., "Climate Security Vulnerability in Asia 1.0" (Strauss Center for International Security and Law, May 2016), https://www.strausscenter.org/images/cepsa/CEPSA_Vulnerability_Brief-1.pdf.

15 These results are discussed in Joshua Busby, Raleigh, Clionadh, and Idean Salehyan, "The Political Geography of Climate Vulnerability, Conflict, and Aid in Africa," in *Peace and Conflict 2014*, ed. Paul K. Huth, Jonathan Wilkenfeld, and David A. Backer (Boulder: Routledge, 2014), 71–91.

16 Here is one way you should not use the data. Do not overlay conflict on vulnerability. As you will find if you try, the CCAPS vulnerability model includes the ACLED conflict data as an indicator in our governance basket. The CEPSA data includes a similar measure of subnational political violence from the Political Instability Task Force.

17 Joshua W. Busby et al., "Identifying Hot Spots of Security Vulnerability Associated with Climate Change in Africa," *Climatic Change* 124, no. 4 (2014): 717–31, http://econpapers.repec.org/article/sprclimat/v_3a124_3ay_3a2014_3ai_3a4_3ap_3a717-731.htm.

18 CCAPS, "CCAPS Final Program Report on 'Climate, Conflict, and Governance in Africa'" (Strauss Center for International Security and Law, November 2016), https://www.strausscenter.org/ccaps-news/ccaps-final-program-report-on-climate-conflict-and-governance-in-africa.html.

19 See https://www.fews.net/

20 See http://www.isciences.com/

Capturing Climate and Security Risks Through Satellites and Earth Observing Technologies

Sinead O'Sullivan[1]

Introduction

It has been well documented that climate change is producing rapid physical changes globally.[2] Some of these changes are observable over short periods of time, while others are only discoverable when comparing the current geographical system to that from thousands of years ago, and are, therefore, less obvious.[3] Climate change has altered the underlying fabric of how communities and cultures exist and cooperate with each other, and this is largely through the physical changes that have occurred in a local context.[4] As globalization and increased sharing of the world's resources increases, diminishing resources in certain geographic locations are quickly becoming problematic and proliferating negative consequences globally.[5]

Some of these geographic locations that are experiencing radical physical changes are simultaneously experiencing political economical changes as well. The geopolitical significance of these changes can be significant; some of these local vulnerabilities can create "epicenters," where there are serious implications for global security. Understanding the emerging risks around these epicenters is of the utmost importance, and understanding how to prepare for and mitigate these risks is the responsibility of all stakeholders in the larger, international context. Satellites and Earth Observation technologies are among the best means for observing how the world is climatically and geographically changing, and should be used going forward as a key tool for decision-making by policy-makers and other key stakeholders.

Earth Observation Technology

The first images from space were taken on the sub-orbital V-2 rocket flight launched by the United States in 1946.[6] From then on, taking images of the Earth from space became a national interest. The first satellite to orbit Earth was in 1957, when the Soviet Union launched Sputnik I.[7] The "Space Race" between the United States and the Soviet Union created accelerated "remote sensing" – scanning of the earth by satellite or aircraft to obtain information about it. Increasingly sophisticated remote sensing instruments were created and placed aboard satellites and aircraft to monitor the Earth's surface.

Moving forward to 2017, there are approximately 4,300 satellites orbiting Earth according to an index maintained by the United Nations Office for Outer Space Affairs (UNOOSA). Approximately 380 of these satellites are being used for Earth observation by both the private sector and governments.[8] In addition to satellites, drones - or Unmanned Aerial Vehicles (UAVs) are they are also commonly known - are becoming an increasingly important tool to collect data about the Earth and how it is being used.

Earth Observation (EO) technologies are vitally important to our understanding of the physical changes affecting the world. These EO technologies are primarily used to do three things; first, to collect data that allows constant monitoring of the variation in climate over time. Second, to allow a process of "change detection" to take place, whereby precise measurements of how geographical locations are changing over time. Third, to use satellite and drone observation in near real-time monitoring and precise response to climate-related events. Being able to observe the Earth in such a granular manner allows not only constant monitoring of the changes that might bring about negative consequences, but the collection of vast amounts of data also enables the scientific models that measure climate change to become predictive, thus allowing better planning around future likely changes.

Emergent Risks

Secondary Effects of Climate Change

Climate change has brought about very specific physical changes that satellites and drones are able to detect easily. There are, however, secondary and tertiary effects of climate change that are harder to observe directly. One secondary effect associated with climate change is a global increase in natural disasters. In 2015, the United States National Oceanic and Atmospheric Administration (NOAA) released a report "Explaining Extreme Events of 2014 from a Climate Perspective". In the report, a

team of international scientists revealed that 50% of the weather extremes experienced in 2014 were influenced by human activity-related climate change. These events included droughts in Syria, a Himalayan snowstorm in Nepal and extreme flooding in Canada. According to the United Nations Office for Disaster Risk Reduction, 90% of recorded major disasters from 1995 to 2015 were linked to climate and weather, including floods, storms, heat waves and droughts. The prediction for future weather events is unanimous among climate scientists: there will be an increased number of natural disasters, and the severity of these disasters will be heightened.

Another secondary effect of climate change is the impact on available natural resources in a given geographic location. In many instances, climate change has led to either a reduction in or removal of natural resources available to communities or states, thus placing heightened or extreme pressures on regions as harsh resource constraints and degradation sparks domestic instability. Scarcity of food and water poses the greatest hazard. Conflict over food and water scarcity is not new in the age of climate change; however, with the drastic rate of change of global temperatures, these conflicts will become more pronounced and frequent.[9] The effects of some of these conflicts have already been seen; there is substantial academic literature relating the Syrian war to water shortages and the Arab Spring, and particularly the Egyptian Uprising to food shortages.[10]

Both natural disasters and natural resource disturbances are easily observable with EO technologies such as satellites and drones. Natural disasters can be very quickly detected through satellite and drone imagery; they are physical in nature and chaotic in behavior.[11] Using methods of change detection in imagery, which have been implemented for several decades, satellite imagery can very quickly detect a natural disaster. They also can be used in certain stages of the disaster management cycle as outlined by the United Nations Office of Disaster Risk Reduction (UNISDR), namely response, rehabilitation, reconstruction and recovery.[12] Given its ability to collect mass amounts of unbiased data very quickly, especially in conditions that are too dangerous for human data collection, EO data is exceptionally useful for measuring, monitoring and even predicting secondary effects of climate change.

Tertiary Effects of Climate Change

Tertiary effects of climate change are much harder to measure through EO technologies, although satellites do play a very vital role. In this instance, third level effects of resource insecurities and natural disasters are largely intertwined with the downstream effects of socio-economic and geopolitical stresses, which can inevitably lead to human disasters. The United Nations deals primarily with response to humanitarian needs and emergencies resulting from conflict and global challenges from climate change and environmental degradation.[13] Humanitarian disasters are defined as single

event or series of events that threaten the health, safety or well being of a community or large group of people.[14] In this instance, famine, the migration of communities and increased conflict are major areas of global concern. It is important to note that these second- and third-level effects often feed into each other and themselves,[15] but to simplify the response to such effects, they usually are treated as independent.

Of these effects, famine and migration are the most difficult to record both on the ground and from aerial EO systems. Satellite imagery has a refresh rate of approximately three days in developed, populated and urbanized areas. However, humanitarian disasters are most prevalent in geographic locations that are not observed by highly refreshed satellites, and thus tracing the movement of people is very difficult when the movement is much faster than the ability of a satellite to capture it. To get around this problem, satellite imagery, and especially imagery captured by drones, has been used to observe refugee camps and surrounding areas of movement. Algorithms have been developed that can take satellite and drone imagery and create an estimate of the camp population, something that is nearly impossible to do on the ground due to the volatility in refugee movements from one camp to another.[16]

A seemingly trivial calculation of a camp's population can have profound effects on both the lives of the refugees in the camp and the economics of disaster management. Knowing, or being able to predict, a camp's population means that there is a streamlining of resources required to sustain the thousands or hundreds of thousands of inhabitants. Satellite imagery has also been used to monitor the impact the settlement of refugees has on natural resources and the quantification of this impact.[17] Lodhi et al use a method of machine learning classification of two images taken in an Afghan refugee camp in northern Pakistan monitoring changes to forest land cover in the area.[18] This reinforces the ability to use satellite data to predict conflict in regions of high numbers of displaced and refugee persons by exploring the fragile relationship between migration and the unexpected tightening of natural resources in states that are already fragile, such as in Pakistan.

Similar to the movement of people, famine and food shortages are difficult to visually detect. Rather than reacting to a famine, satellites (more so than drones) are beginning to be used in a revolutionary way that will predict future food shortages, both globally and within key areas of concern such as epicenters. Within the private sector, U.S.-based TellusLabs is combining decades' worth of satellite imagery and using machine learning to predict economic and environmental future conditions.[19] Within the commodities industry, TellusLabs are working with government agencies to predict crop yields across the United States. Their aim is to expand to international markets and eventually create global grain-supply predictions to locate and prevent weaknesses in the global and local food supply chain.

The United Nations Institute of Training and Research (UNITAR) does food supply chain analysis using satellite images in conflict areas, such as Syria and South Sudan. In an interview, Lars Bromley, the principal analyst for Human Rights and Security at the United Nations Operational Satellite Applications Program (UNOSAT), described the methods undertaken to analyze food stability in regions of unrest: "We have just started a review to look at agricultural production in ISIS-held areas in Syria. Using satellite imagery, we are analyzing how much of the farmland in the area will be able to be harvested in the current growing season. The fear is that, should stability come to the region, there will be food scarcity as farmers have not been able to sow the harvest and even farms that have been sown, have seen their farmers flee the area."

This can be seen in conflict zones globally. He added, "This can be seen in Africa, too. There was a migration of South Sudanese refugees into Uganda who were in search of food security. The conflict there is so serious that the crops couldn't be harvested, and Uganda offered the resources that they badly needed".[20]

Future Recommendations

Earth Observation can provide invaluable global socio-economic, geopolitical insights.[21] As political and economical decision-making become more data-driven, satellites and drones can be valuable tools policy makers should utilize to create sustainable and unbiased policies to reduce the risks that are emerging due to local and global climate change. This new technological landscape, however, is complex and difficult for any one country to navigate alone. There are multiple players across the satellite industry - governments, non-governmental organizations (NGOs) such as the United Nations and the private sector with individual satellite companies distributing different data sources. When it comes to aerial and drone footage, there are complex operational barriers, especially when trying to acquire imagery over hostile zones such as Aleppo in Syria, where a drone or aircraft is likely to come under fire.[22] Trying to collect relevant data from across the multiple sources and integrate it into a format that can be analyzed is challenging. Further, the actual analysis of the imagery is difficult and often requires specially trained engineers to derive relevant analytics and insights from the data.[23] In this context, there are two basic recommendations for policy-makers interested in pursuing this technologically advanced method of mitigating global risks. First, that the collection of data is aggressively pursued where possible. Second, that the international EO community becomes more integrated and that there is end-to-end support for, and across, the stakeholders in the industry. It is vital that in order to pursue a data-driven analysis of climate change implications, the analysis must have enough data to provide accuracy. Many of the methods by which satellites and drones create insights that can be used in these complex scenarios involve machine learning and artificial intelligence. Therefore, it is imperative that the algorithms have enough historical data to "learn" from. This, on a practical level, means that where possible, data from satellites and drones should be taken at any given opportunity and stored so that it can be easily accessed.

To further the second recommendation, the satellite and drone industry is largely fragmented between operations, hardware and software services. There is no single platform from which users can access the highly complex data. There is also the problem of the "digital divide," whereby several governments do not have the same levels of computational access to interpret this heavy data as others. Some countries and agencies, such as the U.S., NASA and the European Space Agency (ESA), provide open-sourced and free data, whereas other private-sector entities such as DigitalGlobe and Planet charge users a fee for accessing the data.

Across the industry, there is a strong need to create an integrated approach at all levels to find an end-to-end solution. This entails a higher level of data integration between the private-sector satellite companies and, even more importantly, a wider range of partnerships among government agencies to allow easier access to this data. One example of a positive approach to collaboration can be seen in the recent Memorandum of Understanding between the South African and Ghanaian governments that laid out the ways in which the two countries would share space-related resources, including EO capabilities, to manage the natural resources that were under duress due to the degradation of the environment caused by climate change.[24]

The concept of sharing spatial capabilities is not new. It is frequently delivered through policy derived by the United Nations Office of Outer Space Affairs, where member states of the United Nations are encouraged to participate and give access of their satellite imagery when possible.[25] These relationships that are created though the United Nations should continue to be strengthened, and the role of the private sector in such partnerships should be highlighted.

Conclusion

As the world moves into a new digital age, policy making should not be left behind. The importance of monitoring, reacting to and predicting climate change-related consequences has never been higher, as evidenced by the current geopolitical phenomena occurring worldwide. The creation of "epicenters" and their ability to have global impacts means that policy-makers are not only encouraged but also required to advance ways in which climate-related problems are dealt with on an international scale. Satellites and drones provide new ways to monitor global changes rapidly and easily, and Earth Observation is fast becoming a tool of national and international security importance. There is much work to be done to create an integrated approach to decision-making from Earth Observation analytics, but the data is readily available to those who seek it, as many do, and use it to prepare for and mitigate against these risks.

Notes

1 Sinead O'Sullivan is a Research Fellow with the Center for Climate and Security.

2 S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller. *Climate Change 2007: The Physical Science Basis*. Working Group, Cambridge: IPCC Fourth Assessment Report (AR4), 2012.

3 Walther, Post, Convey, Menzel, Parmesan, Beebee, Fromentin, Hoegh-Guldberg & Bairlein. "Ecological responses to recent climate change." *Nature* 416, no. 389-395 (March 2002).

4 Gilman, Urban, Tewksbury, Gilchrist, Holt. "A framework for community interactions under climate change." *Trends in Ecology and Evolution* 25, no. 6 (June 2010).

5 Bohle, Downing, Watts. "Climate change and social vulnerability: Toward a sociology and geography of food insecurity." *Global Environmental Change* 4, no. 1 (March 1994).

6 *NASA.gov*. October 10, 2007. accessed at https://history.nasa.gov/sputnik/ (accessed May 1, 2017).

7 NASA. Accessed at https://www.nasa.gov. March 6, 2009. https://www.nasa.gov/multimedia/imagegallery/image_feature_1298.html (accessed May 1, 2017).

8 UNOOSA. *Space Objects Register*. April 25, 2017. Accessed at http://www.unoosa.org/oosa/en/spaceobjectregister/index.html (accessed May 1, 2017).

9 Reuveny. "Cliamte change-induced migration and violent conflict." *Political Geography* 26, no. 6 (2007).

10 Güner. "The Turkish-Syrian war of attrition: The water dispute." *Studies in Conflict and Terrorism* 20, no. 1 (1997).; Gleick. "Water, Drought, Climate Change, and Conflict in Syria." *American Meteorological Society* July (2014).; Feitelson, Tubi. "A main driver or an intermediate variable? Climate change, water and security in the MIddle East." *Global Environmental Change* 44 (2017): 39-48.; Adeel. "Managing Water, Energy, and Food for Long-Term Regional Security." In *The Water, Energy and Food Nexus in the Arab Region*, by Zafar Adeel, 175-191. Springer International Publishing, 2017.

11 Pace, Aloi. "Disaster monitoring and mitigation using aerospace technologies and integrated telecommunication networks." *IEEE Aerospace and Electronic Systems Magazine* 23, no. 4 (2008).

12 Coppola. *Introduction to international disaster management*. Elsevier, 2007.

13 United Nations. *Humanitarian Assistance* http://www.un.org/en/sections/priorities/humanitarian-assistance/ (accessed April 12, 2017).

14 Humanitarian Coalition. http://humanitariancoalition.ca/info-portal/factsheets/what-is-a-humanitarian-crisis (accessed April 15, 2017).

15 Lindley. "Environmental Processes, Political Conflict and Migration." In *Humanitarian Crises and Migration: Causes, Consequences and Responses*. Routledge, 2016.

16 Giada, Groeve, Ehrlich, Soille. "Can satellite images provide useful information on refugee camps?" *International Journal of Remote Sensing* 24, no. 22 (2003).; Giada, Groeve, Ehrlich, Soille. "Information extraction from very high resolution satellite imagery over Lukole refugee camp, Tanzania." *International Journal of Remote Sensing* 24, no. 22 (2003).

17 UNITAR. https://unitar.org/unosat/ (accessed April 3, 2017).

18 Lodhi, Echavarria, Keithley. "Using remote sensing data to monitor land cover changes near Afghan refugee camps in northern Pakistan." *Geocarto International* 12, no. 1 (1998).

19 TellusLabs. http://www.telluslabs.com/ (accessed April 11, 2017).

20 Bromley, Lars, interview by Sinead O'Sullivan. *Principal Analyst, United Nations* (March 30, 2017).

21 OECD. "Earth observation for decision-making." *OECD.org*. March 2017. http://www.oecd.org/environment/indicators-modelling-outlooks/Earth_Observation_for_Decision_Making.pdf (accessed April 27, 2017).

22 Shaar, Choi-Fitzpatrick. "Struggle over Aleppo's story takes to the skies." *Aljazeera*. February 22, 2017. http://www.aljazeera.com/indepth/opinion/2017/02/struggle-aleppo-story-takes-skies-170221105309042.html (accessed March 13, 2017).

23 UN-SPIDER. "UN-SPIDER Capacity-Building." January 25, 2011. http://www.un-spider.org/about/information-material/one-pager-capacity-building (accessed March 3, 2017).

24 The Ghanaian Times. March 30, 2017. http://www.ghanaiantimes.com.gh/ghana-sa-sign-mou-on-environment/ (accessed April 11, 2017).

25 UN Knowledge Portal. http://www.un-spider.org/ (accessed April 11, 2017).

THE CENTER FOR CLIMATE AND SECURITY

www.climateandsecurity.org