CENTER FOR THE NATIONAL INTEREST

Water Crises, Security and Climate Change

Editors: Geoffrey Kemp and Luke Hagberg
with Adam Lammon, Bianca Majumder and Bradley L. Nelson

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Center for the National Interest

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Table of Contents

Maps

Executive Summary

The historically severe drought in Syria from 2006-2011 led to the migration of rural communities to already overburdened urban centers, which concurrent with the state's mismanagement of freshwater resources, helped foment the social unrest and the uprisings against President Bashar al-Assad. The ongoing conflict has had repercussions around the globe with refugees fleeing to, and having an unmistakable political impact upon, neighboring states and Europe. The war in Yemen was rooted in the Arab Spring, but while the attempts to overthrow President Ali Abdullah Saleh were eventually successful, the political transition was not. The overextraction of Yemen's groundwater led to an unprecedented water crisis that has been exacerbated by the civil war. Terrorist cells, militant insurgencies, and foreign interventions have undermined efforts to reform the Yemeni government and address this humanitarian catastrophe.

Conflict over water does not always result in overt violence, although it often produces complex interstate tensions. Water-sharing agreements in South Asia, often drafted by colonial powers, are outdated and have been further complicated by the impact of rising temperatures on the long-term sustainability of waterways fed by glacial melt.

India and Pakistan's dispute over the Indus River's allocation is both complicated by their colonial history and the disputed territory of Kashmir through which the river and its tributaries flow. While resolving this particular issue would be one step of many towards mending their bilateral relations, establishing a basis for cooperation would reduce tensions and meet mutual objectives of stable water supplies. The Helmand River, shared between Iran and Afghanistan, has been the subject of repeated negotiations, since the two countries are at different stages in their infrastructural development and neither efficiently utilizes the freshwater capacity currently allotted to them. Iran's subversive employment of the Taliban against Afghan development projects to prevent losing water resources reveals that non-state actors can be directed by states to exploit issues of water scarcity, or they themselves can target water supplies for their own objectives, as has happened repeatedly in Yemen, Iraq, and Syria.

In the Nile River Delta and the Central Asian Republics, the multilateral nature of disputes over limited freshwater resources only increases the difficulty of negotiations. Upstream states can exert outsized influence over freshwater flows and unilaterally affect downstream flow by building dams for hydropower, agriculture, and development projects. Environmental degradation and independent actions raise the potential for conflict for all invested nations.

In Part II of the monograph, the impact of sea level rise and other climate trends on various regions of the globe and coastal U.S. states are examined. With mass migrations already destabilizing nations around the world, communities dislocated by sea level rise will only worsen the problem. Low-lying islands like the Maldives or the Marshall Islands are facing existential threats and questions about their future sovereignty and national identities, as they may be forced to relocate their populations abroad. Coastal states with low-lying landscapes such as Bangladesh have already suffered enormously from storm surges and cyclones, and more intense storms and flooding are certain to displace many more thousands of people, further straining already tense relations with India. River delta regions face similar threats, with sea level rise inundating coastal regions, worsening the effects of flooding, and saturating fertile regions and freshwater aquifers with salt. Such threats will make negotiations on water issues more tenuous in states like Egypt, Pakistan, and Vietnam, where relations with their neighbors are already precarious.

The United States also faces serious threats posed by sea level rise. Due to Alaska's immense size and proximity to the Arctic, the state will contend with a variety of threats, including sea level rise and stronger storm surges, permafrost melt, and erosion all forcing communities to consider the future integrity of their homes and livelihoods. In other parts of the state, isostatic rebound and relative sea level decline are drying up waterways and threatening important ecosystems and valuable fisheries. Further north, a recursive pattern of melting sea ice and warming seas known as the Albedo effect will produce sea ice decline to levels unprecedented in recorded history, allowing for new avenues of exploration, navigation, and resource exploitation. This is certain to create new challenges for North Atlantic and Arctic diplomacy. Much further south, America's first climate refugees are being displaced from their homes in Southern Louisiana. Major metropolitan areas including Miami and New York City, and the vital Norfolk Naval Station in Hampton Roads, Virginia, are dealing with the record losses to land, property, and investment. And as the projected increases in intensity and destructiveness of hurricane seasons occur as a result of climate change, more lives are likely to be lost and already vulnerable communities will bear the brunt of future struggles.

Considering that climate change is having insidious effects on U.S. military readiness, the U.S. Department of Defense has a role to play in advancing the United States efforts to understand the link between climate change and national security. The Joint Chiefs of Staff and the uniformed heads of each armed services branch are well suited to argue for the reality of climate change impacts and for the long-term preparations needed to meet future climate-related threats while avoiding politicizing the topic. Yet international multilateralism must play a significant role as well. Climate-induced migrations on a massive scale can cause isolationist and authoritarian tendencies in different states. Such a shift could occur at the expense of civil liberties in democratic societies as well as stark economic costs, in addition to complicating efforts to assist the people most adversely affected by climate change.

To mitigate against the threats posed by enclosures, isolationism, and authoritarianism, political, economic, and technical solutions must be found. The international community needs to undergo energy decarbonization, drastically reducing the amount of carbon emissions that are released into the environment, which cannot happen without technological innovation. To promote innovation, public opinion must be educated about the financial, health, and national security costs of carbon emissions. Goods and services which use carbon as a significant input must also be accurately priced to reflect negative externalities. A carbon tax can address the pricing problem, and the revenue can be invested in developing low-carbon energy sources and used to address the disproportionate effect of rising prices on poor communities. These two policies should promote a shift towards renewable and low-carbon energy sources, which will be both more politically feasible, more affordable, and easier than transitioning to a zero-emission economy while meeting the world's rising demand for electricity.

Introduction

The genesis of this study began in 2011 when Geoffrey Kemp was a Transatlantic Fellow at the United States German Marshall Fund's Transatlantic Academy. Together with five other fellows he was the co-author of a monograph titled "The Global Resource Nexus: The Struggles for Land, Energy, Food, Water and Minerals." Based on the structure of this monograph the six authors published a book on the subject in 2014, "Waste, Want or War?"[1] One central theme of these studies concerned the increasing importance of climate change in magnifying the problem of resource scarcity. Based on this preliminary work, the Carnegie Corporation of New York provided the Center for the National Interest with funding to continue this work and to focus increasingly on the national security issues raised by climate change.

Categories of researchers as diverse as physical scientists, economists, and political scientists have been shedding light upon the many facets of climate change's anticipated consequences, while journalists and documentarians have been exposing broad swaths of the U.S. public to climate change's workings and potentially severe effects. Despite the rising focus on climate change in these circles, governments have struggled to keep pace with appreciable action. Several U.S. domestic and international attempts were made to address scientific consensus on climate change preceding the genesis of this study. However, failures such as the U.S. ratification of the Kyoto Protocol in 1997, the Copenhagen Summit in 2009, and The American Clean Energy and Security Act of 2009 (also called the Waxman-Markey Bill) underscored the lack of order and consensus within the political community regarding the issue of climate change.

The United States Department of Defense (DoD), and in particular the United States Navy, has had an unexpectedly outsized impact on the national discussion on climate change, taking the lead on presenting the realities of its impact on domestic security and international relations. In some ways, this is not surprising given that the U.S. Navy has always planned 30-40 years into the future to sustain an effective force and anticipate the occurrence of likely political and technical developments. Working on the maritime frontlines around the globe and at home, the U.S. Navy

[1] Philip Andrews-Speed, Raimund Bleischwitz, Tim Boersma, Corey Johnson, Geoffrey Kemp, and Stacy D. Vandeveer, *Want, Waste or War: The Global Resource Nexus and the Struggle for Land, Energy, Food, Water, and Minerals*, Routledge, 2015.

and the U.S. Coast Guard have firsthand knowledge of how changing weather patterns, natural disasters, and sea level rise are impacting a range of livelihoods.

During the Trump administration, climate change has continued to be a contentiously debated between politicians who believe the threat is real and getting worse, and those who have a more skeptical outlook on the subject. This study does not dwell on these major political disputes within the U.S., but does argue that the realities of what is happening to the global environment require overcoming such disagreements. Organizations like the DoD, financial institutions like the insurance industry, and energy companies are already adopting strong mitigation efforts that address the deleterious effects of climate change. The focus of this study concerns the problems associated with diminishing freshwater supplies and the rising levels of seawater, both of which are in large part attributable to climate change.

This monograph is based on the work of the editors and many talented interns working at the Center over a period of six years. The names of those involved with the study and other supporters of the project are listed at the conclusion of the monograph.

The Organization of This Monograph

The introduction reviews overall impact of fresh and salt water on global national security concerns and the scientific basis for these connections. Part I on freshwater security highlights climate and security issues taking place in the greater Middle East and South-Central Asia, which are crucial to U.S. foreign policy. Part II of the study focuses on the threat of rising sea level facing the coasts of the United States as well as low-lying states and island nations. This section serves to highlight the danger of sea level rise and intensifying storms facing American military infrastructure and the security consequences that would stem from their impairment—whether through increased costs or diminished functionality. It also makes examples of the most immediately vulnerable nations as harbingers of future security concerns stemming from climate change across the globe Chapters are also included on areas that are key to American interests, but which have received less focus in literature that assesses the security implications of climate change, including Bangladesh, the Indus River Basin, and the riparian states located along the Nile River Delta.

This review is by no means comprehensive, and does not cover the problems facing countries like Russia, China, European states, Latin American countries, or sub-Saharan Africa. Multiple countries that are greatly important to U.S. national security and are threatened by climate change are currently studied in detail elsewhere, and are thus not the focus of this monograph. Russia will have to contend with the national security implications of progressively available shipping lanes along its northern border, as well as newly accessible petroleum reserves as the melting of sea ice quickens. Books such as "Russia's Arctic Strategies and the Future of the Far North" (2013) by Marlene Laruelle outlines such challenges.[2] China, too, will face problems as its climate changes; its northern regions may become more susceptible to water shortages, agricultural yields are projected fall throughout the country, while the negative effects of air pollution stand are likely to rise in the country's urban centers. The Asian Development Bank has outlined many of these trends in "Addressing Climate Change Risks, Disasters and Adaptation in the People's

[2] Marlene Laruelle, "Russia's Arctic Strategies and the Future of the Far North" (Routledge, 2013).

Republic of China."[3] Meanwhile, states such as Iran and Mexico will likely continue to struggle against rising desertification. In the former, the disappearance of Lake Urmia could lead to a new environmental disaster at the scale of the highly publicized and heavily monitored Aral Sea catastrophe. In the latter, desertification and more unpredictable weather patterns could lead to more water shortages and higher rates of emigration. This monograph passes over several major instances of international climate threats affecting the United States in favor of focusing in on lesser-discussed matters, which are just as essential to acknowledge.

[3] "Addressing Climate Change Risks, Disasters and Adaptation in the People's Republic of China," *Asian Development Bank,* 2015.

Chapter 1: Water and National Security

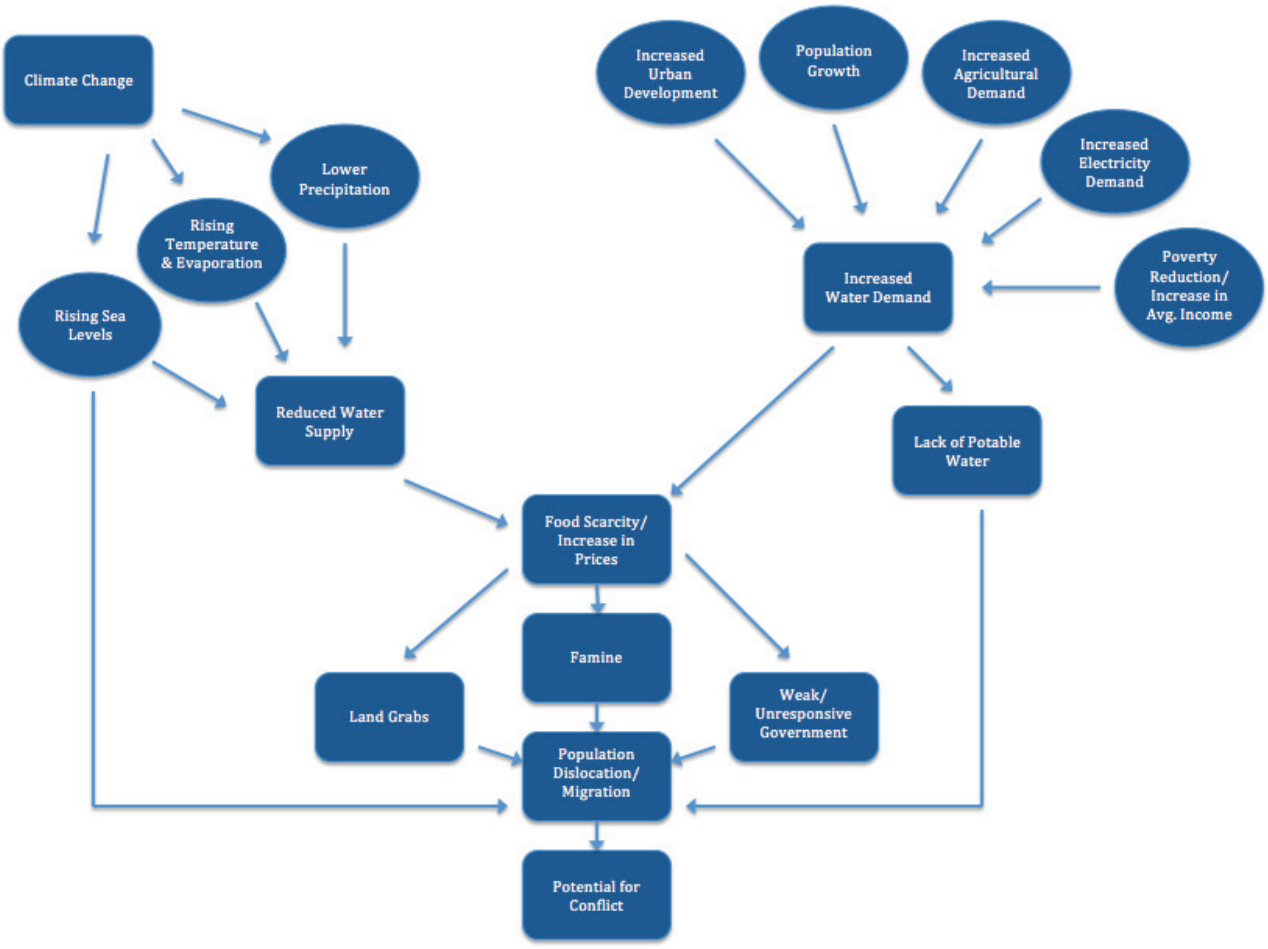
Access to water has been a key factor in the rise of civilizations over thousands of years. Fresh water is essential for human consumption, agriculture and animal husbandry, and industrial production. Access to the sea has been an instrumental feature of the growth of empires, and conflicts over fresh water and the use of seaports have been a structural feature of the strategic history of great powers.

Today, many factors have made water become even more crucial to the calculations of nation-states and individual sub-state actors alike. Regarding fresh water, the combination of population growth, increased demand for food, especially protein, and electricity using hydropower has coincided with examples of mismanagement of freshwater resources and ongoing regional conflicts. Growing evidence shows that global climate change is having negative impacts on freshwater supplies, whether through drought, surface evaporation, salinization of aquifers, or the receding of glaciers that are the source of many of the world's great rivers. Enhanced flooding in some regions will likely contribute to variability in crop harvests and impact food security.

As far as seawater is concerned, sea level rise threatens coastal communities and infrastructure around the globe—endangering some of the world's most economically important cities. While there is uncertainty surrounding the rate at which sea levels will rise into the future—since much will depend on the rate of melting of the Antarctic and Greenland ice caps—the impact on the lowest-lying islands and coasts is already visible in areas as far apart as Alaska and the Maldives Islands.

By identifying connections between climate change, water, and variables of socioeconomic and political interest—what this monograph refers to as the "Resource Nexus"—one can see the interactions between global warming, concurrent population growth, and the potential for conflict. This web of relationships, simplistically shown in the flow-chart below, reveals that policy-makers and other relevant actors must recognize that external environmental factors are affecting issues of national and international security and act to address them.

Illustrating the Resource Nexus



Before addressing the specific challenges of freshwater access and rising sea levels, it is necessary to provide a background of the broader context of geopolitical and economic changes, growing regional conflicts, and the potential impacts of climate change, which establish the overall setting for the themes of this monograph.

Background

Analysts have long debated the significance of resource scarcity as a cause of war, with pessimists predicting that a dramatic increase in resource wars are imminent and optimists expressing confidence that effective international institutions, open economies, and technological innovation should reduce the likelihood of war. The contemporary record suggests that, within regions that have close institutional ties and share common laws and values, resource quarrels are settled judiciously. This has been the case within the North Atlantic community, for example, for the past half-century.

Thus, if good global governance—including adherence to international treaties, conventions, and protocols—good business practices, and regional mechanisms for conflict control and confidence-building measures were the norm across the international system, the successful management of scarcity problems, though difficult, would be substantially easier to envision and achieve. There would be no reason to use coercive measures or, *in extremis*, force to assure or deny access to resources. But at this time in the twenty-first century, these conditions do not exist in many regions. This fact is illustrated throughout this report in discussions of emergent threat factors, challenges, and opportunities. While interstate warfare has generally declined since the end of World War II, some trends point toward a more confrontational and nationalist world where some of the basic rules and norms of the post-WWII order are eroding. This is happening at the very time when the relative power and influence of the North Atlantic community has declined and when the demands humans are making on the Earth's resources grow rapidly with population. Despite growing recognition that global problems require global solutions, we live in a world where power and authority are centered on states. What is changing is the political and economic strength of many great powers—such as China and India—even as the number of states grows. Underlying and sometimes shaping these changing contexts are tensions and hostilities about the origins, nature, and future of the Western liberal order constructed over the last century.

A future of diverse resource insecurities and potentially disastrous climatic changes will impact military conflicts around the world. Beyond the likelihood that such frictions will come from demographic shocks or nationalistic pursuits of scarce resources, these converging trends will significantly alter how states develop national defense and security tools. Indeed, this is already occurring and the capabilities of nation-states to mitigate or adapt to climate change and resource insecurities are being tested in unprecedented ways. Proper strategic planning, as well as investments and international partnerships, will be needed, and states will need to consider that their actions may impact the creation of new norms in the international system and could affect global security.

The United States DoD has been very clear that climate change is a "threat multiplier"[4] that exacerbates existing security challenges, while diminishing our ability to address them.

[4] U.S. Department of Defense, *2014 Quadrennial Defense Review*, 2014, http://archive.defense.gov/pubs/2014_Quadrennial_Defense_Review.pdf.

Climate change will heavily impact key resources such as food and water, which will create ripple effects that, without effective governmental management, can lead to political instability. The real problem is that climate change cannot be easily or simply addressed because, as a global problem that does not recognize borders, it requires multilateral solutions.

In order to examine these varied, climate-related security challenges, we have compiled a series of case studies examining several regions where environmental vulnerability, political instability, and problems of water access are coexistent. In the near term, regions already stricken with conflict and chaos face the greatest challenges, both in terms of the climate-based disruptions they will suffer and the difficulties they will encounter in formulating preventive policies. Yet, in the long term, it is unlikely that any nation or region will avoid the direct or indirect effects of climate change.

Direct Impacts on Water from Climate Change

Climate change will directly impact regional hydrology, and thus, global water supplies, in several key ways. Sea level rise will threaten coastal infrastructure and aquifers, freshwater sources fed by snowpack and glaciers will become less reliable, rising temperatures will increase surface drying and decrease soil moisture, and shifting precipitation patterns may cause arid regions to suffer more frequent and intense droughts while intensifying flooding in wetter regions. Each of these consequences has the potential to compound the complications created by another. Not all areas of the globe will be equally affected, and studies show that regions which are already the most water-insecure will be hit the hardest by climate change.[5] For water-insecure states, developing effective water management policies may be a defining aspect of maintaining future political stability.

Sea level rise has thus far been climate change's most visible effect, and the rate of rise will likely continue accelerating in the coming decades. While the most hyperbolic predictions that large swathes of land will be inundated are unlikely to occur, the potential effects of rising seas will be highly disruptive. The earth's oceans are currently rising at an average rate of 3.2 millimeters per year—up from a rate of 1.2-1.7 millimeters per year from 1900-1990.[6, 7] This is a result of melting polar ice combined with a geophysical phenomenon known as "thermal expansion," whereby the volume of liquid water increases as it stores more heat. Although regional sea level rise can differ from the global mean, the United Nation's 2013 Intergovernmental Panel on Climate Change (IPCC) fifth assessment report projects a 0.52-0.98 meter rise by 2100 in its RCP8.5, or "business as usual," scenario in which the rate of anthropogenic carbon pollution is "consistent with a future with no policy changes to reduce emissions" and is keeping up with

[5] "Ranking the World's Most Water-Stressed Countries in 2040," *World Resources Institute*, August 26, 2015, http://www.wri.org/blog/2015/08/ranking-world%E2%80%99s-most-water-stressed-countries-2040.
[6] U.S. National Aeronautics and Space Administration, *Vital Signs of the Planet: Sea Level*, by Holly Shaftel, March 26, 2018, https://climate.nasa.gov/vital-signs/sea-level/.
[7] Joshua K. Willis et al., "Ocean Portal: Sea Level Rise," *Smithsonian Institution*, 2017. http://ocean.si.edu/sea-level-rise.

expected population growth.[8,9] The RCP6.0 scenario, described as a world where human-induced "…forcing is stabilized shortly after year 2100, which is consistent with the application of a range of technologies and strategies for reducing greenhouse gas emissions," still predicts a 0.38-0.73 meter rise by the end of the century.[10,11]

Furthermore, recent findings concerning the decades-long decay of Antarctic ice shelves have raised the potential for sea level rise to outpace these mainstream predictions.[12] While the rate of rise may seem numerically insignificant at first glance, it will have profound impacts globally if realized. Rising seas may further intensify storm surges, salinize coastal aquifers, exacerbate flooding in low-lying nations, and threaten the existence of many island states. Forty-four percent of the global population lives in coastal areas, ensuring that sea-level rise will impact communities around the world.[13] Although some wealthy nations will be able to adapt by building sea walls such as the Netherland's $7 billion Delta Works, developing nations will struggle, as will developed countries who face particular geographic vulnerabilities to sea level rise. For example, Miami, Florida is built on porous limestone which has allowed its rising water table to seep up from under the streets and severely flood low-lying areas where a sea wall is otherwise holding back the rising coastal ocean. Regardless, infrastructure must not only keep pace with rising ocean waves, but also with the likelihood of intensified storm surges (temporary coastal sea level rise due to a storm) during severe weather events—which may become more frequent with climate change. Additionally, saltwater intrusion from rising sea levels is a threat to groundwater aquifers—a source of drinking water and sanitation. The increased frequency and severity of flooding may drive coastal residents out of their communities, whether through direct threat to home and person (in developing countries) or through spiraling insurance premiums hampering real estate development (a potential future for developed nations).

Globally warming temperatures will also threaten key sources of fresh water: snowpack and mountain glaciers. The gradual, seasonally predictable melting of high-altitude snow and ice provides the water upon which billions of people rely for drinking, plumbing, and agriculture as the runoff recharges local and regional reservoirs.[14] According to the United Nations' Food and Agriculture Organization (FAO), "about 40 percent of the world's irrigation is supported by flows originating in the Himalayan and other large mountain systems (e.g. Rocky Mountains in the

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[8] John A. Church et al., "2013: Sea Level 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,* ed. T.F. Stocker, et al. (Cambridge: Cambridge University Press, 2013), https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter13_FINAL.pdf.

[9] Van Vuuren et al., "The Representative Concentration Pathways: An Overview," *Climatic Change* 109, no. 1-2 (2011).

[10] Church et al., "Sea Level Change."

[11] Van Vuuren et al., "The Representative Concentration Pathways: An Overview."

[12] "SOTC: Ice Shelves," *National Snow and Ice Data Center*, February 12, 2018, https://nsidc.org/cryosphere/sotc/iceshelves.html.

[13] "Human Settlements on the Coast," *UN Atlas of the Oceans*, accessed March 7, 2018, http://www.oceansatlas.org/subtopic/en/c/114/.

[14] Sindya N. Bhanoo, "Billions of People Depend on Water From Shrinking Snowpacks," *The New York Times*, November 17, 2015, https://www.nytimes.com/2015/11/18/science/billions-of-people-depend-on-water-from-shrinking-snowpacks.html.

western United States and Tien Shan in Central Asia)."[15] A warmer world suggests that snowpack accumulation will decrease in the winter months, causing higher freshwater runoff in the winter, but less in the summer months when it is typically utilized for drinking and sanitation. Overtime, as snowpacks fail to recharge in the winter, runoff rates will decrease more rapidly. In a 2012 Nature Climate paper, Stanford climate researcher Noah Diffenbaugh observed that…

> …we see that much of the Northern Hemisphere is dependent on snowpack for water storage….our results suggest that global warming will put increasing pressure on both flood control in the cold season and water availability in the dry season, and that these changes are likely to occur in some of the most densely populated and water-stressed areas of the planet.[16]

Global freshwater demand is expected to increase by 55 percent between 2000 and 2050, driven by population growth and rising demand for agricultural goods.[17] In a world where freshwater demand is projected to outpace recharge rates and gross supply, populations will have to adapt quickly to potentially dwindling snowpack or face dire consequences.

Precipitation and surface drying are other weather variables that will be significantly impacted by climate change. Warmer air causes more precipitation to fall in the form of rain rather than snow, as well as increased evaporation at Earth's surface. For every single degree of warming, the atmosphere's water-holding capacity increases by seven percent.[18] As a result, periods of precipitation will be more intense, with heavy rain or snowfall when precipitation does occur. Intense floods or snow storms will become more frequent in areas that are already at risk, while arid regions are more likely to experience drought and reduced precipitation.

The parts of the world that are already most water-insecure will be most severely impacted by warming temperatures. The Middle East and North Africa are particularly vulnerable.[19] These regions are home to governments with poor track records in water management, and preventive measures often take a back seat to immediate policy concerns like combating violent extremism or political instability. However, because poor water management itself remains a fundamental source of these problems, short-term efforts to address these concerns will be inherently limited in their effectiveness.

Climate Change and Water Security

A threat to water security is a threat to state stability and security. Thus, climate change necessitates a shift in how states approach water security. The 2017 United Nations World Water Development Report estimates that two-thirds of the world's population already faces water scarcity for at least one month per year, and 500 million people live in areas where freshwater

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[15] Hugh Turral, Jacob Burke, and Jean-Marc Faurès, "Climate Change, Water and Food Security," (Rome: Food and Agriculture Organization of the United Nations, 2011), http://www.fao.org/docrep/014/i2096e/i2096e.pdf.
[16] Rob Jordan, "Stanford Study: Climate Change Threatens Freshwater Source for Billions," *Stanford University*, November 11, 2012, https://news.stanford.edu/news/2012/november/future-snowpack-decline-111112.html.
[17] Tim Smedley, "Future - Is the World Running Out of Fresh Water?" *BBC*, April 12, 2017, http://www.bbc.com/future/story/20170412-is-the-world-running-out-of-fresh-water.
[18] Intergovernmental Panel on Climate Change, *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. Qin Solomon et al., (Cambridge: Cambridge University Press, 2007).
http://oceanservice.noaa.gov/education/pd/climate/factsheets/howprecipitation.pdf.
[19] "Vulnerability of arid and semi-arid regions to climate change: impacts and adaptive strategies," *Arab Water Council,* (2009), http://www.preventionweb.net/files/12914_PersPap09.AridandSemiAridRegions1.pdf.

consumption exceeds local resources by a factor of two, requiring water imports.[20] As the scarcity of water in arid regions worsens, there will be new opportunities for non-state actors to seize control of water as a path to security and legitimacy in weak states—a tactic already being utilized in Iraq and Syria. In the realm of water security, climate change will result in new avenues for asymmetrical warfare, create new obstacles to peace, and require massive fiscal investments in infrastructure.

The notion that water security has the potential to drive conflict is not new. Academics in the past have warned of "water wars" erupting between strong states over scarce water resources.[21] When observing the growing demand and scarcity of water, it seemed plausible that states would be willing to wage war to secure their water needs. These wars never materialized as envisioned, but the issues have manifested themselves in the water disputes that have grown in number over the last sixty years.

Traditional water disputes stem from conflicts over river flows shared between riparian neighbors. To wage war with the intention of securing water is counter-intuitive, since "hydro-hegemons," have the power to manipulate water flows—a tactic Turkey has used against Syria in the past.[22] If threatened by inter-state conflict over water, upstream states could pollute or restrict the flow of water supplies in retaliation. In some cases, even if a state did manage to win a "water war," there could be extreme costs in developing the infrastructure to divert water flows or transport water over great distances. Yet in other cases—for instance, if the victor could pump more water from a shared basin—the costs would be lower. Nonetheless, in almost every dispute, cooperation is a more cost-effective and sustainable method of securing the resource. Nearly 60 percent of freshwater resources globally are lost due to poor infrastructure (such as leaky pipes), meaning that effective water management is a powerful tool in conflict prevention or resolution.[23]

The hyperbolic expectation of water playing a central role in a traditional war between states may never emerge, but it is increasingly taking on a secondary role in aggravating pre-existing tensions. A 2012 U.S. Intelligence Community assessment notes that water is particularly vulnerable to non-state actors.[24] Terrorist and insurgent groups do not follow state norms of water sharing, and can act as provocateurs that exploit or intentionally create water scarcity. Control over water, as well as the ability to deny their opponents access to it, creates opportunities for insurgents to gain legitimacy and shape the battlefield environment in their favor. When the Islamic State controlled large areas of Iraq and Syria, it seized dams, halted water flows to its enemies, and transited forces across the shallows they created.[25] State actors have been complicit in behavior as

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[20] "Wastewater: The Untapped Resource," in *United Nations World Water Development Report 2017*, (Paris: United Nations World Water Assessment Programme, 2017), http://unesdoc.unesco.org/images/0024/002471/247153e.pdf.
[21] Peter H. Gleick, "Water, War & Peace in the Middle East," *Environment: Science and Policy for Sustainable Development* 36, no. 3 (1994): 6-42.
[22] Michael Collins, "Water War? Turkey Cuts Water Supply to Syria. Euphrates Shut Down," *Global Research*, June 2014, http://www.globalresearch.ca/water-war-turkey-cuts-water-supply-to-syria-euphrates-shut-down/5386054.
[23] Karin Krchnak, "Water Scarcity Overview," *World Wildlife Foundation*, http://www.worldwildlife.org/threats/water-scarcity.
[24] U.S. Intelligence Community, *Intelligence Community Assessment: Global Water Security,* Washington, DC: February 2012, http://www.dni.gov/files/documents/Special%20Report_ICA%20Global%20Water%20Security.pdf.
[25] Alan Duke and Hamdi Alkshalim, "ISIS Claims Gains, Takes Control of Iraq's Largest Hydroelectric Dam," *CNN*, August 2014, http://www.cnn.com/2014/08/03/world/meast/iraq-crisis-isis/.

well, as Iran has offered terrorists bounties to destroy Afghanistan's dams along the Helmand River.[26] Climate change could further incentivize these behaviors in the future by creating environments of scarcity that contribute to terrorism and political instability.

Climate Change and Food Security

Initial estimates of the impact of warming on food production surmised that, essentially, longer growing seasons in higher latitudes would offset the effects of unfavorable heat in regions closer to the equator. However, a more exhaustive assessment of the region-specifics of warming—including such factors as increased weather variability, droughts, heat waves, ocean acidification, and land erosion—has revealed that climate change is likely to cause significant negative impacts on food production overall.

Climate change will likely make drought more frequent and more intense in already dry areas. Joseph Romm estimated in his book *Climate Change: What Everyone Needs to Know* that, "as much as one third of the Earth's currently habitable and arable land faces a near permanent drying this century." While precipitation estimates have been traditionally difficult to model, predicted general trends based on fundamental physical attributes and mechanisms of the Earth's atmosphere are more reliable. Owing to this, predictions for the end of the century have consistently estimated a "general drying" of the subtropics—an evolution that the IPCC states will create widespread stress on agriculture.[27] A regional attribution study estimated that anthropogenically-forced climate change increased the likelihood of a drought as severe as the 2006-2011 drought in Syria by two to three times over natural variability alone.[28] During this period, the "Fertile Crescent" subregion was plagued by food shortages, helping to foment civil unrest. Drought's conflict-compounding affect in the Middle East is threatening regional stability, and climate change's contribution to intensifying droughts and enhancing desertification will exacerbate this problem.

Major food production regions in the West are facing drying troubles as well, spelling difficulties for regional economies and food prices. The most notable example is the U.S. state of California (the 6th largest economy in the world as of 2016).[29] The impending severity of predicted droughts, intensified by climate change, threatens California's $45.3 billion agriculture industry, which includes one-third of the United States' vegetable production and two-thirds of its fruit and nut production.[30] Scientists estimated that the 2012-2016 drought in California (associated with an estimated economic impact of $2.7 billion) was made 15-20 percent more intense due to the effects

[26] Fatemah Aman, "Afghan Water Infrastructure Threatens Iran, Regional Stability," *Al Monitor*, January 7, 2013, http://www.al-monitor.com/pulse/originals/2013/01/afghanwatershortageiranpakistan.html.
[27] David S. Battisti, and Rosamond L. Naylor, "Historical Warnings of Future Food Insecurity with Unprecedented Seasonal Heat," *Science* 323, no. 5911 (2009): 240-244.
[28] 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): 3241-3246.
[29] Dale Kasler, "California Economy Surges to No. 6 in Global Rankings," *The Sacramento Bee*, June 14, 2016, http://www.sacbee.com/news/business/article83780667.html.
[30] California Department of Food and Agriculture, *California Agricultural Production Statistics*, 2016, https://www.cdfa.ca.gov/statistics/.

climate change.[31, 32] While surface water and snowpack levels have since returned to normal thanks to above-average rain and snow fall accumulation from late 2016 through spring 2017, the state's groundwater aquifers will likely take decades to recover—serving as a warning of future freshwater troubles for the state in the face of climate change.[33, 34]

The most costly single-year drought on record in the United States was the Texan drought of 2011, an extreme drought which had an estimated economic impact of $5.2 billion and, according to one study published by the *American Meteorological Society*, occurred in a year where extreme heat events were twenty times more likely than normal given similar relevant meteorological and geophysical metrics.[35, 36] Texas is the U.S. leader in farming and ranching, and the drought-plagued years following 2011 pushed beef prices to their highest level in nearly three decades.[37] The frequency and intensity of droughts are a major influence in agricultural productivity, and although global trends are hard to predict with precision, scientists are very concerned with just how food security will evolve with them.[38]

More intense heat waves are also a cause for concern due to their potentially devastating impact on food production, independent of water supply. The 2003 European heat wave inflicted an estimated $13 billion of uninsured agricultural costs.[39] In 2010, heat-caused devastation of Russian wheat production led the Russian government to ban the export of wheat.[40] While hotter temperatures can benefit crop yields under some circumstances, extreme events, such as heat waves, have entirely negative effects. According to a 2009 paper in *Science*, the basic rule for staple crops, such as corn, wheat, and soy, is that for every degree Celsius of warming above optimal growing temperatures, yields decrease by 10 percent. However, some estimates predict

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[31] Dale Kasler and Phillip Reese, "California Drought Impact Pegged at $2.7 Billion," *The Sacramento Bee,* August 2015, http://www.sacbee.com/news/state/california/water-and-drought/article31396805.html.
[32] Justin Gillis, "California Drought Is Made Worse by Global Warming, Scientists Say," *The New York Times,* August 20, 2015, https://www.nytimes.com/2015/08/21/science/climate-change-intensifies-california-drought-scientists-say.html?_r=0.
[33] U.S. Department of the Interior, U.S. Geological Survey, *California Drought*, March 7, 2018, https://ca.water.usgs.gov/data/drought/.
[34] California Department of Food and Agriculture, Assembly Committee on Jobs, Economic Development, and the Economy, *California Agriculture*, June 30, 2016, http://ajed.assembly.ca.gov/sites/ajed.assembly.ca.gov/files/California%20Agriculture%20Fast%20Facts%20updated%20June%2030%202016.pdf
[35] Blair Fannin, "Texas Agricultural Drought Losses Reach Record $5.2 billion," *Texas A&M AgriLife,* August, 2011, https://today.agrilife.org/2011/08/17/texas-agricultural-drought-losses-reach-record-5-2-billion/.
[36] Thomas Peterson, Peter Stott, and Stephanie Herring, "Explaining Extreme Events of 2011 from a Climate Perspective," *American Meteorological Society,* 2012: http://www1.ncdc.noaa.gov/pub/data/cmb/bams-sotc/2011-peterson-et-al.pdf.
[37] Rabeea Tahir, "Drought Pushes Beef Prices to Record Levels," *The Texas Tribune*, April 30, 2014, https://www.texastribune.org/2014/04/30/record-drought-takes-toll-dinner-tables/.
[38] John R. Porter, et al., "Food Security and Food Production Systems," 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,* ed. C.B. Field, et al. (Cambridge: Cambridge University Press, 2014), pp. 485-533.
[39] "Climate Change 2007: Impacts, Adaptation and Vulnerability," in *Working Group II Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, (New York: Cambridge University Press, 2007), https://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4_wg2_full_report.pdf.
[40] George Welton, "The Impact of Russia's 2010 Grain Export Ban," *Oxfam*, June 28, 2011, https://www.oxfam.org/sites/www.oxfam.org/files/rr-impact-russias-grain-export-ban-280611-en.pdf.

yield decreases as high as 15 to 17 percent for every degree Celsius increase.[41] These estimates are based on "optimal conditions," where plots are tightly controlled and managed using modern irrigation methods and pesticides. Under sub-optimal conditions, yield decreases could be significantly larger per increase in average temperatures. While "carbon fertilization" and higher temperatures can theoretically contribute to an increase overall biomass, it is not helpful for staple crops which rely on a multitude of other agricultural metrics that are changing in a warming world.

As explained by David Battisti, an atmospheric scientist at the University of Washington, the tropics are already beyond optimal temperatures for staple grains and an increase in temperature at the globe's mid-latitudes could push these regions beyond optimal growing temperatures. Even a small temperature increase in these latter areas, known as the world's "breadbasket" because they produce the majority of the world's grains, could lead to great decreases in yields over the long term and cause significant yield volatility in the short to medium term.[42]

Some have suggested the possibility of seeing increased grain productivity throughout the planet's higher latitudes because increases in temperature would lengthen the growing season in those regions. However, yields in regions like northern Canada and Russia are limited by the quality of their soil, and for the most part, nearly all the arable land is already being utilized.[43] Ultimately, there simply is not enough topsoil in those regions to grow grains, no matter how hospitable the climate becomes. According to the United Nations Food and Agriculture Organization (FAO), it takes about 1,000 years for three centimeters of topsoil to form, so it is going to be a long while before the northern latitudes can take over as the major regions for global grain production.[44]

Increased flooding due to climate change in some regions of the world is also expected to have negative impacts on food production. While already dry areas are in danger of further drying, wet areas are expected to become wetter and incur a higher risk of flooding as a result of climate change.[45] In the short term, flooding due to an increase in the frequency of severe precipitation and increased snow meltwater runoff into rivers and reservoirs has the potential to oversaturate fields, encourage water-borne crop disease, and lower soil oxygen content in affected areas.[46] According to the FAO, "the frequency of extreme precipitation is predicted to increase dramatically in countries and climates as far apart as the United Kingdom (by 5 times in the north and west) and Bangladesh (by 3–7 times) with consequent increases in the duration, extent and severity of flooding."[47] For example, scientists have projected that Bangladesh's flood-prone areas will increase by 23-29 percent with a global temperature rise of 2°C by end of the century.

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[41] Battisti, "Historical Warnings of Future Food Insecurity."
[42] David Wallace-Wells, "The Uninhabitable Earth, Annotated Edition," *New York Magazine*, July 14, 2017, http://nymag.com/daily/intelligencer/2017/07/climate-change-earth-too-hot-for-humans-annotated.html.
[43] Ibid.
[44] Chris Arsenault, "Only 60 Years of Farming Left if Soil Degradation Continues," *Reuters* via the *Scientific American*, https://www.scientificamerican.com/article/only-60-years-of-farming-left-if-soil-degradation-continues/.
[45] "3.4.3 Floods and Droughts," in *AR4 WGII Chapter 3: Fresh Water Resources and their Management, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, 2007, https://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch3s3-4-3.html.
[46] Emmalea Ernest, "Impact of Flooded and Saturated Soil Conditions on Field Crops," College of Agriculture & Natural Resources, *University of Delaware*, June 14, 2013, https://extension.udel.edu/weeklycropupdate/?p=5793.
[47] Turral et al., *Climate Change, Water and Food Security*.

Unfortunately, flooding and severe rain events are expected to damage growing fields and introduce higher variability in crop yields.[48] The IPCC has estimated that up to 20 percent of the world's population live in river basins that are likely to be affected by increased flood hazard by the 2080s.[49]

Crop pests are also expected to become more invasive with climate change because they typically prefer hotter, wetter climates. A study done by the University of Exeter in the United Kingdom analyzed hundreds of crop pests and pathogens and demonstrated that their average latitudinal ranges have been shifting poleward by about 2.7 km per year since 1960.[50] This means that areas previously out of the range of common biological threats to food production are being introduced to them at a worrying rate. Historical examples of massive devastation from crop pests and disease—like the Irish potato famine of the 1840s or the 1943 Great Bengal Famine—have shown the world that these instances can cause millions of deaths, dizzying economic costs, and social instability from mass migrations.[51]

Climate change also poses serious risks for food security in the marine sector, which would drastically affect the global food market and regions that are heavily dependent on the sea for sustenance. According to the FAO, in 2013 fish accounted for about 17 percent of the global population's intake of animal protein, comprised 6.7 percent of all protein consumed, and provided more than 3.1 billion people with almost 20 percent of their average per capita intake of animal protein.[52] Climate change threatens the oceans—and thus consumable marine life and its associated economic sectors—by introducing a new source of ocean acidification, altering the optimal environmental temperatures and salinity of marine populations in key areas, and accelerating de-oxygenation of waters. As the world has already begun to see, climate change threatens to continue altering oceanic conditions at a pace too rapid for existing food systems to keep up.

The interface between the atmosphere and the ocean allows for significant exchanges in energy and chemical constituents. The ocean is currently the largest sink for anthropogenic carbon dioxide, having absorbed about 40 percent of human emissions since the beginning of the industrial era.[53] Dissolving CO_2 leads to a predictable chemical reaction that lowers the pH of the waters to a higher acidity, with measureable historic and present change. The Smithsonian National Museum of Natural History states that "in the past 200 years alone, ocean water has become 30 percent more acidic—faster than any known change in ocean chemistry in the last 50 million years." Even small changes in pH can effect marine populations by disturbing physiological processes involved in growth, health maintenance, and reproduction—risking the availability and quality of marine food sources. Several major food sources, including mollusks and the coral reefs essential for

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[48] "3.4.3 Floods and Droughts," *Intergovernmental Panel on Climate Change*.
[49] Ibid.
[50] Daniel P. Bebber, Mark A. T. Ramotowski, and Sarah J. Gurr, "Crop Pests and Pathogens Move Polewards in a Warming World," *Nature Climate Change* 3, no. 11 (2013): 985-988.
[51] Bryan Walsh, "A Warmer World Will Mean More Pests and Pathogens for Crops," *Time*, September 02, 2013, http://science.time.com/2013/09/02/a-warmer-world-will-mean-more-pests-and-pathogens-for-crops/.
[52] U.N. Food and Agriculture Organization, *The State of World Fisheries and Aquaculture*, 2016, http://www.fao.org/3/a-i5555e.pdf.
[53] Tim Devries, Mark Holzer, and Francois Primeau, "Recent Increase in Oceanic Carbon Uptake Driven by Weaker Upper-Ocean Overturning," *Nature* 542, no. 7640 (2017): 215-218.

major regional fisheries, rely on predictable ocean pH levels to properly develop their exoskeletons and are especially vulnerable to slight changes in local acidity.[54] Mollusk populations struggling with higher acidity will suffer from a reduction in physical size and numbers. Coral reefs form the nurseries for a quarter of the oceans fish, and many communities are completely reliant on them for their fisheries and tourist-based economies.[55]

Aside from a chemical exchange, a warming atmosphere has and will continue to exchange heat with the ocean—warming the waters and quickly altering the environment of consumable fish. The FAO has quoted research saying that "changes in fish distributions in response to climate variations have already been observed, generally involving poleward expansions of warmer-water species and poleward contractions of colder-water species."[56] Coral reefs, the ecosystem of many consumable marine species, are also extremely sensitive to changes in ambient temperatures, which can stress the coral to the point of bleaching and enhanced vulnerability. A bleached coral requires an average of 10 to 15 years to recover, unless it incurs additive vulnerability from another bleaching event. As global temperatures have increased, the median time between severe coral bleaching events has decreased to six years, and global coral reef health has been adversely affected.[57] Unfortunately, communities reliant on fisheries for food security and economic prosperity without a high adaptive capacity in these areas will have to contend with a quickly changing marine environment moving toward unprecedented local conditions.

Another major climate-induced danger to ocean food supplies is the growth of oceanic "dead zones," where low oxygen levels can empty vast oceanic areas of life.[58] National Geographic states that "these low-oxygen zones occur naturally, but have grown by more than 4.5 million square kilometers—an area roughly as large as the entire European Union—just since the mid-20th century."[59] Warmer water holds less dissolved oxygen, promotes higher rates of oxygen metabolism by existing organisms, and increases the buoyancy of surface waters, thus preventing the oxygenated upper layer of the ocean from mixing downwards into the deeper ocean. Additionally, human activity, through the use of nitrogen-rich fertilizers and their subsequent river runoff into larger water basins, has worsened the problem by creating massive algal blooms that drastically lower the oxygen levels in the water and kill nearby marine lifeforms. The growth of these cancer-like "dead zones," which choke off sea life and wipe out fisheries, has already decimated major areas in the Gulf of Mexico.[60] Oxygen depletion in the ocean further contributes to marine ecosystems' increasing fragility, and will put food security at risk if dead zones are expected to expand with continued climate change.

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[54] Jennifer Bennett, "Ocean Portal: Ocean Acidification," *Smithsonian Institution*, 2017, http://ocean.si.edu/ocean-acidification.
[55] "Coral reefs: importance," *World Wildlife Fund*, http://wwf.panda.org/about_our_earth/blue_planet/coasts/coral_reefs/coral_importance/.
[56] "Climate Change Will Have Strong Impact on Fisheries," *Food and Agriculture Organization*, July 10, 2008, http://www.fao.org/newsroom/en/news/2008/1000876/index.html.
[57] Kendra Pierre-Louis, and Brad Plumer. "Global Warming's Toll on Coral Reefs: As if They're 'Ravaged by War'." *The New York Times*, January 04, 2018, https://www.nytimes.com/2018/01/04/climate/coral-reefs-bleaching.html.
[58] Craig Welch, "Climate Change Is Suffocating Large Parts of the Ocean," *National Geographic,* January 04, 2018, https://news.nationalgeographic.com/2018/01/climate-change-suffocating-low-oxygen-zones-ocean/.
[59] Ibid.
[60] Ibid.

Nonetheless, climate change will affect food production in many ways, not all of which are easily anticipated. Sea level rise combined with periods of increasingly intense precipitation will lead to more frequent flooding, which could destroy crops. Warmer temperatures may lengthen high-latitude growing periods, but also have the potential to abet the spread of pests and disease and dry out lower latitudes. Warming oceans will threaten fisheries through sudden changes in the ambient environment of marine life, not all of which organisms can readily adapt to. All of these specific food security threats will pose enormous challenges, particularly in already vulnerable regions, over the coming decades.

Food Insecurity and Conflict

The exploitation of food vulnerabilities, whether denying food via sieges or scorched earth tactics, has always been a part of warfare and organized conflict. The strategic importance of food is a key element of asymmetrical warfare, as dwindling food supplies will provide non-state actors with more opportunities to achieve their aims through the control of food, while simultaneously destabilizing the ability of state governments to feed their people and promote internal stability. Failing to account for the causal linkage between climate change and resource insecurity may induce resource-driven conflicts both within and among states, especially in regions with high rates of subsistence agriculture.

The connection between food shortage and conflict is supported by numerous examples. As was typical with water security, there are few cases where food shortage was the primary cause for conflict, but there are many instances where food insecurity has been a secondary escalator of political upheaval. Located in one of the most famine-vulnerable regions on the planet, Somalia has been struck by frequent famines. The famine that occurred during Somalia's civil war in the 1990s allowed insurgents to seize food supplies to strengthen themselves at their foes' expense, and the famine which lasted from 2010-2012 resulted in 260,000 deaths.[61] In this latter case, Al Shabaab (an extremist group allied with Al Qaeda) capitalized on the turmoil and levied taxes on food aid, while simultaneously decrying the international community's refusal to purchase food from Somali farmers.[62]

In a conversation with *New York Magazine*, Marshall Burke, an assistant professor at Stanford University, noted increasing speculation that the elevated level of strife over the past generation across the Middle East is at least partially due to the pressures of global warming. Burke finds that the main reasons for the relationship between climate and conflict stems from economics and agriculture. His analysis shows that higher temperatures reduce agricultural productivity and freshwater resources, which leads to lower crop yields, and incentivizes the most desperate individuals to seek assistance from their governments.[63] However, if the basic needs of the most desperate and marginalized individuals are ignored or suppressed by the governing regime, grievances develop and conflict becomes much more likely. In most cases, intra-state wars are started by small numbers of individuals with few alternatives to acquire the basic resources to survive.

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[61] "Somalia Famine 'Killed 260,000 People,'" *BBC News*, May 2, 2013, http://www.bbc.com/news/world-africa-22380352.

[62] Mark Tran, "Al-Shabaab in Somalia Exploited Aid Agencies During 2011 Famine – report," *The Guardian,* December 8, 2013, http://www.theguardian.com/global-development/2013/dec/09/al-shabaab-somalia-exploited-aid-agencies-famine.

[63] Wallace-Wells, "Uninhabitable Earth."

Despite similarities to other forms of resource security, food is different because of both the ease with which it may be transported and preserved, and the minimal infrastructure requirements for its distribution. The globalization of food has had many benefits, but, because of climate change, this interdependence also may produce severe challenges. Climate change is a global phenomenon, and increases the likelihood of events that will stymie food production—particularly in agriculturally important regions. Food-insecure regions that already struggle to produce food—notably the Middle East and North Africa—will face even greater difficulties as the overall availability of food declines in international markets. Even worse, water insecurity is forcing some states, including Saudi Arabia, which was famous for its emphasis on self-sufficiency, to increasingly rely on food imports.[64] In a report titled *Food Security and Food Production Systems*, the IPCC stated with high confidence that the effects of climate change have been felt on terrestrial food production in several areas of the world—and that most consequences have been negative. In this same report, its authors concluded that, "it is very likely that changes in temperature and precipitation, without considering effects of CO_2, will lead to increased food prices by 2050, with estimated increases ranging from 3 to 84%."[65] As food prices rise, food security in developing states will continue to erode.

Higher Temperatures and Conflict

Data supports a positive correlation between higher temperatures and higher rates of conflict. One study in *Science* by Hsiang, Burke, and Miguel estimated that increases in temperatures or rainfall resulted in increased interpersonal violence and intergroup conflict.[66] There are multiple mechanisms that could link changes in the climate to higher rates of conflict. Reductions in freshwater sources, decreases in food availability, and the resulting increases in prices are some of the most notable factors that are likely contributing to this correlation, but others may yet be identified. The authors of the aforementioned study estimate that "if the entire planet went through an average of 3.6 F of warming by 2050—an optimistic limit set at the 2009 Copenhagen conference—[the world would] see personal crime rise by 16 percent and intergroup conflicts surge by 50 percent."[67]

Climate and Human Security

Throughout human history, threats to public health have caused security vulnerabilities and conflict through forced migrations and interference in the labor force. The World Health Organization (WHO) has stated that climate change is expected to cause around 250,000 additional deaths per year between 2030 and 2050—with causes ranging from malnutrition, malaria and diarrhea, to heat stress.[68] The WHO estimates that "the direct damage costs [of climate change] to health (i.e. excluding costs in health-determining sectors such as agriculture and water and

[64] Javier Blas, "Saudi Wells Running Dry – of Water – Spell End of Desert Wheat," *Bloomberg,* November 3, 2015. http://www.bloomberg.com/news/articles/2015-11-04/saudi-wells-running-dry-of-water-spell-end-of-desert-wheat.
[65] Porter et al., "Food Security and Food Production Systems."
[66] Solomon M. Hsiang, Marshall Burke, and Edward Miguel, "Quantifying the Influence of Climate on Human Conflict," *Science* 341, no. 6151 (September 2013).
[67] Joseph Stromberg, "Climate Change Could Increase Armed Conflicts By 50 Percent Worldwide," *Smithsonian,* August 01, 2013, https://www.smithsonianmag.com/science-nature/climate-change-could-increase-armed-conflicts-by-50-percent-worldwide-21877093/.
[68] "Climate Change and Health," *World Health Organization*, July 2017, http://www.who.int/mediacentre/factsheets/fs266/en/.

sanitation), [will] be between US$ 2-4 billion/year by 2030."[69] Unfortunately, areas with weak health infrastructure in developing countries will be the least able to handle the potential crisis."[70]

As climate change progresses, a rise in global average temperatures will lead to more frequent, more intense, and longer heat waves, which will have a significant effect on human health.[71] The U.S. Environmental Protection Agency (EPA) characterizes a discrete extreme heating event as, a "period of summertime weather that [is] substantially hotter and/or more humid than typical for a given location at that time of year." The EPA contends that, "these changes will lead to an increase in heat-related deaths in the United States—reaching as much as thousands to tens of thousands of additional deaths each year by the end of the century during summer months." For example, the heat wave that struck Europe in the summer of 2003 led to more than 70,000 recorded excess deaths; the U.S. Center for Disease Control reports that the July 1995 heat wave in Chicago—one of the most extreme heat events in recent U.S. history—resulted in over 650 deaths.[72] In addition to increasing mortality rates, an extreme outcome of heat waves, general human health is negatively impacted by heat-related afflictions likes rashes, cramps, heat exhaustion, and heat stroke, and atmospheric changes in ozone levels and air pollution—driving more people to emergency rooms.[73] Older people already susceptible to respiratory and cardiovascular complications are particularly vulnerable to these problems and their health may worsen due to dangerously high levels of atmospheric pollutants.[74]

While excessive heat can greatly affect people residing in northern latitudes where they are less prepared to cope with rising temperatures, arid regions are likely to contend with severe heat waves alongside other climate-change induced threats to longer term habitability.[75] A study published by *Nature Climate Change* projects that by the end of the century, decennial heat waves in Doha, Abu Dhabi, and Bandar Abbas could produce temperatures which exceed the maximum threshold, or "wet bulb maximum," of 170ºF at which humans can physically survive. This threshold, which accounts for heat and humidity levels, is the point at which the human body can no longer perform the natural functions that allow it to cool.[76] If heat stress on public health does indeed progress to this level, significant changes in culture, lifestyle, and infrastructure will have to keep up in higher latitudes, whereas already warm, dry places may see human migration to more habitable areas.

The World Health Organization further warns the public that, "climatic conditions strongly affect water-borne diseases and diseases transmitted through insects, snails or other cold blooded

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[69] Ibid.
[70] Ibid.
[71] "The Heat is On: Causes of Hospitalization Due to Heat Waves Identified," *Harvard School of Public Health*, December 23, 2014, https://www.hsph.harvard.edu/news/press-releases/the-heat-is-on-causes-of-hospitalization-due-to-heat-waves-identified/.
[72] U.S. Center for Disease Control, National Center for Environmental Health, *Climate Change and Extreme Heat Events*, November 2008, https://www.cdc.gov/climateandhealth/pubs/climatechangeandextremeheatevents.pdf.
[73] "The Heat is On," *Harvard University School of Public Health*.
[74] "Climate Change and Health," *World Health Organization*.
[75] U.S. Environmental Protection Agency, *Climate Impacts on Human Health*, January 19, 2017, https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-human-health_.html.
[76] "These Cities May Soon Be Unlivable Thanks to Climate Change," *Time*, October 26, 2015, http://time.com/4087092/climate-change-heat-wave/.

animals."[77] A warming world has the potential to lengthen the transmission seasons of certain vector-borne diseases and alter (possibly expanding) their geographic range as their optimal environmental conditions spread or shift. Experts are continually warning that the spread of malaria—a human parasite transmitted by *Anopheles* mosquitos—is strongly influenced by climate and weather variables, and cases are expected to increase as the world warms. Malaria currently kills over 400,000 people every year – and the parasite's link to extreme climatic events has been extensively studied. In the early 1900s, the Punjab region of India suffered periodic malaria epidemics, with "excessive monsoon rainfall and high humidity [being] identified early on as a major influence, enhancing mosquito breeding and survival. Recent analyses have shown that the malaria epidemic risk increases around five-fold in the year after an El Niño event," when the region is much wetter.[78]

In addition, studies suggest that climate change is linked to the increased spread of dengue fever—a viral infection that affects many developing countries with underreported mortality data.[79] With climate change abetting the spread of disease, developing countries, which are already the primary centers of these infections, will have to contend with possible increased risks of outbreaks in the future. While developed countries may not directly suffer from the spread of such diseases, their impacts will be felt in the form of migration from impacted regions and the humanitarian expenditures to ameliorate the suffering.

Sea Level Rise and American Military Infrastructure

The United States' formidable military capabilities stem from a high capacity to project force, which in turn relies on global basing. Budget sequestration has already reduced the military's effectiveness while also demonstrating the political obstacles to future military funding. Climate change threatens military infrastructure through direct effects (primarily sea level rise and extreme weather events) that will raise the costs of maintaining military bases at a time when the United States is dealing with scarcer financial resources. Given the coming challenges of climate-related resource insecurity, the United States may face emerging threats with diminished capabilities.

Taken in isolation, climate change's impacts on the military can seem manageable. However, considering that U.S. military operations span the globe, even a relatively modest increase in operating costs due to environmental factors may pose problems for future U.S. defense budgets.[80] Climate change, taken in combination with domestic pressure to reduce defense spending, is going to change the future security environment. This will be even more apparent as regional powers will have more opportunities to expand their influence in a multipolar world, and will have to deal with problems exacerbated by escalating resource insecurity.

Climate change is already posing risks to U.S. military installations, and past instances of weather-related challenges serve as examples for what may come in the future. In the Indian

[77] "Climate Change and Health," *World Health Organization*.
[78] "Climate Change and Infectious Diseases," in *Climate Change and Human Health – Risk and Responses*, (World Health Organization, 2003), http://www.who.int/globalchange/climate/summary/en/index5.html.
[79] "Climate Change and Health," *World Health Organization*.
[80] Louis Jacobson, "Ron Paul says U.S. has military personnel in 130 nations and 900 overseas bases," *PolitiFact*, September 14, 2011, http://www.politifact.com/truth-o-meter/statements/2011/sep/14/ron-paul/ron-paul-says-us-has-military-personnel-130-nation/.

Ocean, the Diego Garcia military base allows the United States and its allies to project power in the Middle East and Southeast Asia and, repair and resupply its military vessels. Diego Garcia is only one meter above sea level, and is severely threatened by sea level rise, limiting the ability of Atlantic and the Pacific forces to connect and coordinate.[81] Military installations at Norfolk, Virginia are also to face problems from more frequent flooding.[82] Other aspects of climate change, such as extreme weather events and shifting theaters of operation, will also pose challenges for the military and its infrastructure. For example, in 1995 Hurricane Andrew nearly destroyed all of Florida's Homestead Air Force Base,[83] while in 2004 Hurricane Katrina caused $500 million of damage to Keesler Air Force Base.[84] Extreme weather events that can cause this sort of damage are expected to become both more frequent and more intense as climate change worsens.

The Importance of Case Studies

Climate change is a difficult security threat to assess. The effects of climate change on the planet are complex, and predictions of which regions are vulnerable to climate change must take into account a multitude of factors. Still, detailed analyses of regional examples highlighting already-occurring climate issues can yield key insights for future policy. In this monograph, we present a number of case studies to specifically assess where and how climate change will exacerbate existing geopolitical tensions. These particular cases have been selected not only because they have received less attention than many of the other places which are being threatened by climate change, but because they have lessons to teach us about the problems afflicting the greater Middle East. The case studies are divided between Parts I and II. Part I focuses on disputes stemming from fresh water scarcity and disputes over river-water exploitation. Part II concentrates on the impacts of sea level rise on vulnerable countries and regions.

[81] Catherine Foley, "Military Basing and Climate Change," *American Security Project,* November 2012, http://americansecurityproject.org/wp-content/uploads/2012/11/Military-Basing-and-Climate-Change.pdf
[82] Lori Montgomery, "In Norfolk, Evidence of Climate Change is on The Streets at High Tide," *The Washington Post*, 2014, https://www.washingtonpost.com/business/economy/in-norfolk-evidence-of-climate-change-is-in-the-streets-at-high-tide/2014/05/31/fe3ae860-e71f-11e3-8f90-73e071f3d637_story.html.
[83] Foley, "Military Basing and Climate Change."
[84] "Keesler Air Force Base Eluded Cut Only to Be Crippled by Katrina," *Los Angeles Times*, September 12, 2005, http://articles.latimes.com/2005/sep/12/nation/na-keesler12.

Part I: Fresh Water Scarcity and Security Challenges in the Greater Middle East and South-Central Asia

Introduction

Drought, famine, and resource insecurity are some of the most prominent security issues arising from climate change. Around the world, increasing temperatures and highly unpredictable weather patterns increase the likelihood and severity of such occurrences. These potentially disastrous trends are likely to become more prevalent over time and are increasingly important, yet often overlooked, factors in fostering conflict. In Syria, a severe drought and the resulting food insecurity, coupled with the outbreak of the "Arab Spring" protests, primed the nation for destabilization which lead to the eventual outbreak of the Syrian Civil War. In the same region, water scarcity undoubtedly played a role in promoting the instability plaguing Yemen today, where civil war and humanitarian crises have become the norm. These two cases, both discussed in detail in this part of the review, serve as illustrations of civil conflict exacerbated by climate change.

Not every conflict fueled by climate change is intra-state: resource scarcity, especially in the case of water, has the potential to breed inter-state conflict as well. In the Helmand, Nile, and Indus River Basins, competition for increasingly scarce water resources has led to political conflict between neighboring states. Such animosity could potentially escalate into military conflict if the conditions further deteriorate and the parties are unable to reach a sustainable political agreement over the control of water resources in South Asia and North Africa. This section assesses the specific historic and climatic causes of the tensions and provides an outline for how to resolve them, both in these specific cases and in the many similar ones that have arisen around the world.

Water conflict in the Central Asian post-Soviet states is similar to the tensions in the Helmand and Indus River Basins. However, the causes of these strains stem from very different factors than those in the latter examples. While no deep-rooted historical animosity exists between the Central Asian republics, the collapse of the Soviet Union left an important vacuum of governance that highlights the need for strong multilateral mechanisms to resolve resource allocation issues. Furthermore, the region contains what remains of the Aral Sea, one of the worst environmental disasters on the planet. The discussion of Central Asia includes an analysis of efforts to deal with the effects of such an environmental catastrophe, as well as of rehabilitation projects aiming at bringing back a semblance of balance to the ecosystem.

Famine and resource insecurity plagues many regions where climate change is exacerbating drought. North Africa's issues might prove especially severe, as rising temperatures and desertification are creating water shortages and a drop in agricultural yields where severe food scarcity is already an issue. Similarly, many communities in Asia and Oceania have endangered freshwater supplies, threatening critical agricultural practices. As such situations worsen, the lack of strong water-sharing agreements could easily lead to conflict. While this paper does not include extensive discussion of such cases, this does not reflect a failure to acknowledge their importance. Instead, the six cases selected to be part of this review highlight threats facing countries around the globe. The lessons learned from their analyses can be applied to cases of drought, famine, and resource insecurity, which prove particularly relevant to American interests and foreign policy objectives.

Chapter 2: Drought and the Syrian Crisis

What began as local protests in the southern Syrian city of Deraa in 2011 has devolved into one of the bloodiest civil conflicts in recent history. The Syrian Civil War has emerged as a complex, multi-sided struggle, pitting the long-entrenched authoritarian regime of President Bashar al-Assad against pro-democracy moderate rebels, Kurdish groups seeking autonomy, and more extreme Islamist elements—not to mention the various foreign governments that are supporting assorted parties.

The factors that led to the civil war are equally diverse and complicated. Many see the Syrian Civil War as an outgrowth of the broad trend of pro-democracy movements in the Arab world in the early 2010s (the "Arab Spring"), but this is not the entire story. Years of authoritarian governance did increase tensions in Syria, as did decades of violent repression, but other factors contributed to the Syrian uprising as well. One such factor was the severe drought that ravaged the country from 2006 to 2011, one of the worst in Syria's recorded history. Coupled with the mismanagement of natural resources by the Assad regime (including the subsidization of water-intensive crops and encouragement of wasteful flood irrigation), the drought contributed to massive crop failures and a decline in livestock. During this period, millions were driven into extreme poverty.

The resulting mass migrations to Syria's cities had serious consequences. The over 1.5 million Syrians who left rural areas for urban centers placed added strain on cities already suffering from poor infrastructure and filled with refugees of the Iraq War.[85] The social tensions that arose from the Syrian drought, in conjunction with other factors, culminated in the uprisings that ultimately led to civil war, which has claimed nearly half a million lives and displaced, both internally and abroad, some twelve million people.[86] While the drought in Syria was not the only factor that led to war, it was an important one. Recognizing the connections between climate change and drought and their subsequent connections to social trends is essential in understanding

[85] Kelley et al., "Climate change in the Fertile Crescent."
[86] "Syria's Civil War Explained From the Beginning," *Al Jazeera*, February 22, 2018, https://www.aljazeera.com/news/2016/05/syria-civil-war-explained-160505084119966.html.

how to mitigate the negative social impacts of a changing environment and avoid analogous conflicts.

The Syrian Civil War remains an issue of central concern to U.S. foreign policy. The conflict has developed into a proxy war, pitting rebel opposition factions supported by the United States, the Arab Gulf states, and Turkey against the Assad government, backed by its foreign patrons in Russia and Iran. The war's outcome has consequences ranging far beyond the borders of Syria, as the struggle for the country has been one of the main causes of strategic realignment in the region.

Government Agriculture Policy

The largest of the Levantine states, Syria's climatic conditions vary widely. On its western coast, Syria enjoys a mild Mediterranean climate, while the east of the country is mainly desert. As a whole, the country has limited water resources and droughts are common: there have been droughts nearly every other year for the past fifty.[87] Over 60 percent of Syria is considered water scarce, with little rainfall available during the growing season.[88] Aside from rainfall, Syria relies on rivers for its surface water acquisition. The country enjoys access to twenty-one major rivers, most notably the Euphrates, but shares twelve of these with neighbors, making it dependent on water sharing agreements, particularly with Turkey and Iraq. Due to decreased rainfall, however, many of these rivers are no more than seasonal streams.[89] On the eve of the civil war, water availability fell while water demand rose. Poor agricultural policies, inefficient irrigation practices, and outdated infrastructure exacerbated these problems.

Under the Assad regime, agricultural policies incentivized the cultivation of water-intensive crops such as cotton and wheat. While both are highly profitable crops, they are also extremely thirsty, and the agricultural sector consumed roughly 80 percent of the country's total available water before the war.[90] The decision to incentivize such crops in an increasingly arid region played a major role in increasing the level of vulnerability to prolonged periods of drought. The policy may have also played a major role in undermining internal security, the regime's stability and legitimacy, and the state's economic productivity.

The regime seems to have intentionally made the perilous decision of hoarding state funds while pursuing agricultural policies that increased GDP over the short term but risked significant loses over the long run. Instead of pursuing its comparative advantage in producing goods or crops that have a lower opportunity cost than its competitors, such as goods that are labor-intensive but also less water intensive. The fateful decision to put short term economic gains before sustainable production should be a lesson to other countries in the region and around the world that are considering means of adapting to an increasingly unpredictable climate.

[87] Perrihan Al-Riffai et al., "Droughts in Syria: An Assessment of Impacts and Options for Improving the Resilience of the Poor," *Quarterly Journal of International Agriculture* 1, no. 51 (2012).
[88] Ibid.
[89] Ibid.
[90] Adnan Al-Nahhas, "Modern Irrigation in Syria," *Damascus University Journal* 27, no. 2 (2011).

In addition, the Assad regime held off on updating irrigation techniques to more efficient systems.[91] More than 80 percent of irrigated areas in Syria utilize traditional surface irrigation, which, while effective, require 30 to 40 percent more water than modern drip irrigation.[92, 93] In addition to poor irrigative practices, the water infrastructure itself is subject to massive amounts of unneeded loss. For example, the water network for Damascus loses upwards of 60 percent of the water that it carries due to leaks in the system.[94]

Recent Drought

The structural deficiencies in Syria—poor agricultural policies, poor irrigative techniques, and abysmal infrastructure—coupled with an overall shortage of water resources, left the country in a precarious situation leading up to 2006. A five-year drought affecting up to 60 percent of the country quickly became one of the worst in recorded history[95]; 75 percent of Syria's crops were decimated, 85 percent of its livestock were lost, and food prices dramatically rose.[96] These loses forced the government to import wheat in 2008 for the first time since the 1990s,[97] and by 2009, over 800,000 Syrians had lost their livelihoods.[98] The severe food shortages, coupled with rising food prices, led to widespread food insecurity in Syria during the drought years, and by 2008, the UN estimated that 2 to 4 million people were driven into extreme poverty.[99]

Climate Change and Environmental Effects

In desperate need of water, many Syrians turned to pumping groundwater from wells to supplement their needs. As more wells were constructed, the groundwater level in Syria dropped dramatically.[100] Not only did this raise concerns about the quality of water in remaining aquifers, but it also meant that these reserves were harder to access. Increased groundwater extraction is particularly troublesome for Syria given that many of its aquifers are non-renewable, meaning that the recharge rates for such aquifers are essentially insignificant.[101, 102] The drought also affected the health of grasslands, on which livestock depend. Years of overgrazing fields, a growing

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[91] Hannu Juusola, "The Internal Dimensions of Water Security: The Drought Crisis in Northeastern Syria*,"* in *Managing Blue Gold: New Perspectives on Water Security in the Levantine Middle East*, ed. Mari Luomi (Helsinki: Finnish Institute of Foreign Affairs, 2010), 21-35.
[92] Al-Nahhas, "Modern Irrigation in Syria."
[93] "Syria: Drought Pushing Millions into Poverty," *IRIN News*, September 9, 2010, http://www.irinnews.org/report/90442/syria-drought-pushing-millions-poverty.
[94] Ibid.
[95] Francisco Femia and Caitlin Werrell, "Climate Change Before and After the Arab Awakening: The Cases of Syria and Libya," in *The Arab Spring and Climate Change*, ed. Caitlin Werrel and Francesco Femia (Washington, D.C.: Center for American Progress, 2013), 23-32. https://www.americanprogress.org/issues/security/reports/2013/02/28/54579/the-arab-spring-and-climate-change/..
[96] Brad Plumer, "Drought Helped Cause Syria's War. Will Climate Change Bring More Like It?*, Washington Post*, September 10, 2013, https://www.washingtonpost.com/news/wonk/wp/2013/09/10/drought-helped-caused-syrias-war-will-climate-change-bring-more-like-it/?utm_term=.2737d6d09101.
[97] Juusola, "The Internal Dimensions of Water Security."
[98] Worth, "Earth is Parched Where Syrian Farms Thrived."
[99] U.N. General Assembly, *Report of the Special Rapporteur on the right to food, Olivier De Schutter,* January 27, 2011, http://undocs.org/A/HRC/16/49/Add.2.
[100] Kelley et al., "Climate change in the Fertile Crescent."
[101] Juusola, "The Internal Dimensions of Water Security."
[102] Robert Maliva and Thomas Missimer, "Non-Renewable Groundwater Resources," in *Arid Lands Water Evaluation and Management* (Berlin: Springer, 2012), 27-951.

population, and a decline in precipitation have led to the desertification of grazing lands, forcing people off their traditional lands.

While droughts are a common natural occurrence in the Fertile Crescent, many researchers argue that this drought was worsened by climate change. These claims are based partly on comparisons between observed trends and climate models of a changing environment. Two notable predicted shifts include a weakening of winds that bring moist air to Syria from the Mediterranean, and higher temperatures which accelerate evaporation.[103] Both of these predicted phenomena were observed during Syria's drought, from 2006 to 2011, and along with other factors helped increase the likelihood of a severe drought by two to three times.[104]

Social Consequences

The drought also set off a wave of migrations, contributing to instability around the country. Many rural citizens were unable to survive the drought in their home regions. With no farming or pastoral opportunities in the countryside, many migrated to Syria's cities. The scale of these migrations, especially for Syria's already overburdened urban centers, was immense. Because the Assad regime's policies largely ignored water scarcity issues and sustainable agriculture, the drought destroyed many farming communities and led to the migration of over 1.5 million people to urban areas.[105] After the drought began, settlements composed largely of displaced rural migrants formed on the outskirts of Damascus, Hama, Homs, Aleppo, and Deraa. This internal migration exacerbated pre-existing social and economic strains caused in part by Syria's Iraqi and Palestinian refugee communities, and the Assad regime did little to address the situation. The regime's disregard for urgent issues of water access served as a catalyst for a massive mobilization of opposition to the regime.

One of the earliest flashpoints of unrest in Syria was the rural farming town of Daraa, which was hit especially hard by the five-year drought prior to the uprising, and had received little assistance from the Assad regime.[106] Gradually, disenfranchised citizens throughout Syria began questioning their country's distribution of power, which contributed to widespread discontent and non-violent protests by citizens. The beginning of armed rebellion and then civil war only commenced once the Assad regime's security forces began rounding up and shooting protesters in the street. The callous gunning down of protesters and opposition members was, in combination with the regime's decision to set free jihadists from Syrian jails, a cynical ploy to militarize the conflict and tarnish the opposition with the stain of Islamist radicalism. The regime thereby sought to turn the conflict to its military and political advantage.

[103] Henry Fountain, "Researchers Link Syrian Conflict to a Drought Made Worse by Climate Change," *The New York Times*, March 2, 2015, https://www.nytimes.com/2015/03/03/science/earth/study-links-syria-conflict-to-drought-caused-by-climate-change.html.
[104] Kelley et al., "Climate Change in the Fertile Crescent."
[105] Ibid.
[106] Plumer, "Drought Helped Cause Syria's War."

Chapter 3: Yemen's Water Crisis and State Collapse

Yemen is home to some of the earliest-irrigated lands in human history. For centuries, farmers in the area practiced ecologically sustainable agricultural techniques, allowing the country to support a relatively large population despite its limited water resources. But in recent years, even before the ongoing tumultuous civil war began, Yemen employed unsustainable irrigation practices and suffered from devastating levels of groundwater extraction that may have dangerous consequences.

Yemen is already facing an unprecedented water crisis, as it is one of the world's ten most water-scarce countries. Annual per capita water availability in Yemen is a mere 135 cubic meters, while it is 1,250 in the Middle East and North Africa (MENA) region as a whole and 7,500 globally.[107] This puts Yemen's per capita water supply well below the world water poverty line of 1,000 cubic meters. In some remote areas, drinking water is down to less than one quart per person per day.[108] Reliance on limited groundwater, a lack of rainwater collection infrastructure, and the destruction caused by the ongoing civil war force some 13 million Yemenis—half the population— to struggle daily to find clean water.[109]

Existing social and economic concerns, poor governance and poverty, and interventions by foreign powers including Saudi Arabia, Iran, and the United States have only further complicated Yemen's problems. As the impacts of climate change, such as the country's worsening aridity, become increasingly severe, Yemen's struggle to provide the most basic of resources for its people's lives and livelihoods will, without serious innovation and assistance, become dire.

[107] "Groundwater Management and Agricultural Development in Yemen," *Ministry of Water and Environment, National Water Resources Authority*, *Republic of Yemen* 2009, http://www.un.org/esa/dsd/dsd_aofw_wat/wat_pdfs/meetings/ws0109/2_Yemen_Salem.pdf.
[108] Gerald Lichtenthaeler, "Water Conflict and Cooperation in Yemen," *Middle East Report* 254 (Spring 2010).
[109] Frederika Whitehead, "Water Scarcity in Yemen: The Country's Forgotten Conflict," *The Guardian*, April 2, 2015, https://www.theguardian.com/global-development-professionals-network/2015/apr/02/water-scarcity-yemen-conflict.

Yemeni Agriculture

Yemen's agricultural sector consumes roughly 90 percent of the country's water resources: forty-five percent of cultivated land in Yemen depends on rainfall for irrigation, while the remaining 55 percent is irrigated by groundwater and surface water from seasonal floods.[110] Unfortunately, Yemen has no permanent rivers.[111] Until the early 1970s, a small-scale agricultural sector maintained a balance between the supply and demand of water resources. However, the introduction of deep tube wells in subsequent years led to a drastic expansion of land available for cultivation. From 1970 to 2004, the area of irrigated land increased from 37,000 to 407,000 hectares, 40 percent of which was totally reliant on water from deep groundwater aquifers.[112] Instead of sustainable irrigation techniques, such as collecting and storing rainwater, drilling for limited groundwater has become the norm. Many diesel and electric pumps have also significantly diminished the water supply in several of the country's key aquifers.

Yemen is draining its aquifers by three to six meters annually (10 to 20 feet), severely threatening the country's agriculture, economy, and basic access to adequate drinking water.[113] Some analysts posited that the capital Sana'a would run out of water in 2017, but while this did not come to pass, it epitomizes the widespread concern over Yemen's precarious water situation. The conflict with Saudi Arabia has only exacerbated the problem.[114] Yemen's demand for water has outstripped the country's renewable supplies. The estimated groundwater supply is approximately 1,000 million cubic meters (MCM) and the average surface water supply is 1,500 MCM, giving the country a total renewable water resource sum of only 2,500 MCM. Yet the total demand for water in Yemen is estimated to be 3,400 MCM.[115] This shortfall underscores the severe scarcity which Yemen will continue to confront going forward.

Contributing to the increase in water usage is the increasing cultivation of *qat,* a plant with leaves containing a mild narcotic. The vast majority of Yemenis, including 90 percent of men, some 70-plus percent of women, and over 15 percent of children under the age of twelve chew *qat* regularly.[116] It is estimated that *qat* cultivation, which rises 12 percent annually, alone accounts for 40 percent of all groundwater used in irrigation and is lowering the water table level drastically, by three to six meters a year.[117] Despite its water intensive nature, *qat* serves an important role in the nation's emerging cash economy—it is responsible for one-third of agricultural GDP and 6 percent of overall GDP.[118] Therefore, *qat* cultivation cannot simply be stopped, despite its depletion of Yemen's water resources.

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[110] Qahtan Yehya A. M. Al-Asbahi, "Water Resources Information in Yemen," *International Work Session on Water Statistics,* (2005), http://www.yemenwater.org/wp-content/uploads/2015/04/pap_wasess3a3yemen.pdf.
[111] U.S. Library of Congress Federal Research Division, *Country Profile: Yemen*, August 2008, https://www.loc.gov/rr/frd/cs/profiles/Yemen-new.pdf.
[112] Lichtenthaeler, "Water Conflict and Cooperation in Yemen."
[113] Ibid.
[114] "Three Yemen Cities Run Out of Clean Water Due to Lack of Fuel for Pumps: ICRC," *Reuters* November 17, 2017, https://www.reuters.com/article/us-yemen-security-blockade/three-yemen-cities-run-out-of-clean-water-due-to-lack-of-fuel-for-pumps-icrc-idUSKBN1DH1Q2.
[115] Al-Asbahi, "Water Resources Information in Yemen."
[116] "Khat chewing in Yemen: turning over a new leaf," *Bulletin of the World Health Organization* 86, no. 10 (2008): 737-816. http://www.who.int/bulletin/volumes/86/10/08-011008/en/.
[117] Ibid.
[118] Lichtenthaeler, "Water conflict and cooperation in Yemen."

Population & Poverty

According to the World Bank, Yemen's population growth rate is one of the highest in the world, and has doubled in less than 25 years. The annual national population growth rate is about 3.5 percent, and higher rates in urban areas are increasing the burden on cities' water infrastructure.[119] Sana'a's emergence as the economic and cultural center of the country over the past two decades has led to increasing urbanization, with historical figures showing that the population has doubled every ten years since the 1950s, a rate that makes it one of the fastest growing cities in the world.[120] With more people comes higher demand for water, making it possible that Sana'a may soon run out.

Yemen is one of the poorest countries in the Arab world. The poverty rate, which was already worsening prior to the ongoing crisis, rose from 42 percent of the population in 2009 to 54.5 percent in 2012.[121] The unemployment rate has risen to 40 percent for the entire population, while it stands at over 60 percent among youths. Furthermore, an estimated 58 percent of Yemen's population is in need of humanitarian assistance. The most crucial humanitarian issues include food insecurity; malnutrition among children; a lack of safe drinking water and adequate sanitation facilities; poor access to healthcare; human rights violations and other forms of abuse; and a lack of services and jobs in regions to which displaced people have returned.[122]

Such deep poverty has fueled increased civil unrest as marginalized citizens begin to feel abandoned by their government. The presence of poverty in Yemen, coupled with its lack of water security, had a serious impact on the rise of civil disorder and violence in the country. In 2011, hundreds of thousands of protesters, angry with a government that had failed to provide them with basic services, like access to clean water, and respect their legal and human rights, went into the streets and squares demanding an end to the regime of President Ali Abdullah Saleh. These protests eventually led to his ouster.[123]

Climate Vulnerability

Climate change is likely to reduce the quantity and quality of groundwater resources in Yemen. Unfortunately for Yemen, groundwater is the only viable resource in most arid and semi-arid environments that can provide enough water for human consumption and agricultural production for both rural and urban populations.[124] As stated before, Yemen has no permanent rivers. Arid regions in Yemen have irregular and infrequent periods of precipitation, leading to a low average supply of rainfall, and making perennial streams uncommon. Channels called *wadis* have seasonal flow and no significant output during the long dry periods, but do supply Yemen with intermittent surface fresh water. Ultimately, Yemen's aquifers are highly sensitive to

[119] Craig Giesecke, "Yemen's Water Crisis: review of background and potential solutions," *USAID* June 15, 2012 http://www.yemenwater.org/wp-content/uploads/2014/10/pnadm060.pdf.
[120] Gunter Zeug and Sandra Eckert, "Population Growth and Its Expression in Spatial Built-Up Patterns: The Sana'a, Yemen Case Study," *Remote Sensing* 2 (2010): 1014-1034.
[121] "The World Bank in Yemen," *The World Bank*, April 1, 2017, http://www.worldbank.org/en/country/yemen/overview.
[122] "Half of Yemenis live below poverty line," *Al-Monitor,* January 2014, http://www.al-monitor.com/pulse/security/2014/01/yemen-poverty-conflict-food-insecurity.html.
[123] Ibid.
[124] Nicholas Robins and S. Fergusson, "Groundwater Scarcity and Conflict – Managing Hotspots," *Earth Perspectives* 1, no. 1 (2014): 1-9.

variations in annual rainfall and can be exhausted during dry years. Perhaps the most serious water issue facing the country concerns the Sana'a sandstone basin aquifer that supplies Yemen's capital city with drinking water, from which over-extraction is threatening the availability of water to the millions who live there. Another stressor is that a third of the country's workforce is employed in agriculture, an economic sector which is threatened by dwindling water supplies.[125] A forced reduction in agricultural employment due to a lack of water for irrigation could put further strains on Yemen's already high unemployment rates and further destabilize the country.

The effects of climate change on these aquifers threaten the livelihoods of local communities who depend on them for water. Climate change and rising temperatures will lead to higher water demand while simultaneously depleting water supplies by reducing recharge rates and increasing the stress on groundwater systems. Groundwater storage will inevitably be subjected to increasing rates of net loss, reducing an aquifer's capacity to supply extra resources during dry seasons. This, in turn, will continuously stress irrigated agriculture and the domestic water supply for human consumption. Due to the semi-arid and arid climate, not only will dry periods and periods of water stress increase in duration, but substitute water sources will not be widely available. Communities will therefore have to adapt to gradually deteriorating conditions, leading to an overall decrease in irrigated areas (and therefore a decline in agricultural production and employment), and possibly necessitating the costly importation of drinking water.[126]

Government Illegitimacy, Poor Infrastructure, and Urbanization

The Yemeni Minister of Water, Abdelsalam Razzaz, said before the war that "the water crisis is more about institutions than water and it basically amounts to the absence of the state. So long as that's missing, the water is a site for pillage."[127] Yemen has faced a major obstacle in managing its water crisis as the government lacked legitimacy and the institutional capacity to strongly impose laws and regulations. Its inability to improve water infrastructure and management only made matters worse. Existing irrigation infrastructure is only about 30 to 40 percent efficient, and though the Yemeni government had tried to improve irrigation techniques, through either localized systems or improved surface irrigation systems, the irrigated area under these improved systems accounts for only 4 percent of the total area irrigated by groundwater.[128] With Yemen in the grips of a protracted civil war, there is no authority with the capacity to address such issues.

In the absence of government action, illegal wells have become the norm in Yemen as water becomes increasingly scarce. Farmers are now drilling additional wells as short-term solutions to their water needs, further contributing to the nation's water crisis. Yemen's previous minister of water estimated that 99 percent of all extracted groundwater is unlicensed and that there are about 800 illegally operated drilling sites in the country.[129] Weak government authority and institutions are ineffective in preventing this. In fact, in many cases, government authorities are complicit in the usage of these illegal wells. Razzaz claimed in 2012 that nearly all government and tribal leaders had illegal wells for personal use, and stated that the government has been

[125] "Employment in Agriculture (% of Total Employment) (Modeled ILO Estimate)," *The World Bank,* March 2017, https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS.
[126] Ibid.
[127] Joseph Logan, "Rampant Water 'Pillage' is Sucking Yemen Dry," *Reuters,* March 28, 2012, http://www.reuters.com/article/2012/03/28/us-yemen-water-idUSBRE82R0RZ20120328.
[128] Al-Asbahi, "Water Resources Information in Yemen."
[129] Giesecke, "Yemen's Water Crisis."

culpable in their prevalence: "The state—let's put that in quotation marks, since there really isn't one—allowed and helped and took part in the uncontrolled digging of wells."[130]

The national water crisis affects urban and rural Yemenis in distinct ways. 65 percent of Yemenis live in rural areas,[131] but most of the country's water supply is being diverted to Sana'a, since it is the country's main economic hub. Even with this diversion, only a very small proportion of Yemeni families in Sana'a are connected to the municipal water supply. In Sana'a, fewer than half of all homes are connected to the state's water pipelines, and they expect to have water flowing through their taps only twice a week. The underground water pipelines are old and poorly maintained, resulting in the loss of up to 60 percent of Yemen's water in urban areas through leakage.[132] The situation is particularly dire in the industrial city of Taiz, where at times its inhabitants have water service just one day per month. However, urban areas still benefit from subsidized water, much cheaper than water from trucks which most rural residents must buy.[133]

The inequality between urban and rural water supply is exacerbated by the diversion of water from rural areas and directed to urban areas. In rural areas, some women spend four to five hours a day collecting water. For some children, collecting water is viewed as a job, preventing them from going to school. The U.N. International Children's Emergency Fund's (UNICEF) former water sanitation and hygiene specialist for Yemen, Ghassan Madieh, says Yemenis are angry with those controlling water resources, and they blame the government for inadequate funding, governance, and support for water projects.[134] Violence amongst individuals is often sparked over access to fresh water, with one report in a pro-government newspaper estimating that 70 to 80 percent of conflicts in rural areas are related to water. The Yemeni Ministry of the Interior likewise contends that clashes over water are killing up to 4,000 people a year, although this may be a low estimate.[135]

Civil War in Yemen

Yemen's dire environmental situation is mirrored by its grave political circumstances. The Yemeni uprising began in 2011, amidst other Arab Spring protests in the Middle East and North Africa. In its early stages, Yemeni civilians protested against poor economic conditions, youth unemployment, and political corruption. These demands escalated as protesters began to call for President Ali Abdullah Saleh to resign. Demonstrations further intensified as confrontations between the government and the opposition became more violent. In June 2011, President Saleh was injured in an assassination attempt when a bomb was detonated inside his presidential palace, killing seven and injuring several others. The next day, Saleh declared Abd Rabbuh Mansur Hadi, then his Vice President, to be acting president while he flew to Saudi Arabia for treatment. After his departure, Saleh never resumed his role as president. In November 2011, Saleh signed a deal

[130] Logan, "Rampant Water 'Pillage' is Sucking Yemen dry."
[131] "Rural population (% of total population)," *World Bank* 2016, https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS.
[132] Laura Kasinof, "At Heart of Yemen's Conflicts: Water Crisis," *The Christian Science Monitor*, November 5, 2009, https://www.csmonitor.com/World/Middle-East/2009/1105/p06s13-wome.html.
[133] Whitehead, "Water Scarcity in Yemen: The Country's Forgotten Conflict."
[134] Ibid.
[135] Ibid.

to transfer his powers under an agreement brokered by the Gulf Cooperation Council (GCC).[136] In February 2012, Yemeni presidential elections elected Hadi—who ran unopposed—as the new leader of the country, marking an end to Saleh's 33-year rule.[137]

Hadi's assumption of power, however, provided false hope for the country's future stability, as Saleh's loyalists in the parliament and other government institutions had grown rich through his regime's corruption and were reluctant to cooperate with the new leader.[138] At the same time, unrepresented Houthi peoples in the north instigated Yemen's current crisis. The Houthis are a large minority Zaidi Shia insurgent group based in the mountainous areas of northwestern Yemen and have been fighting the government intermittently since 2004, when Saleh still held power. Since the inauguration of President Hadi, the Houthis have sought national power.[139] In September of 2014, the Houthi rebels took control of Sana'a, which led to Hadi's seemingly forced resignation in January of 2015. Since then, the Houthis have been in control of the government, despite Hadi's pronouncement to rescind his resignation.[140]

Yemen has descended into a chaotic conflict between several groups. The main struggle is between forces loyal to President Hadi and the Houthis. Yemen's security forces have split loyalties, with some backing Hadi and others cooperating with the Houthis. Former President Saleh has also supported the Houthis in an apparent bid to reassume power (although the arrangement later collapsed and cost Saleh his life). Both sides are fighting al-Qaeda in the Arabian Peninsula (AQAP), which has staged several deadly attacks from its strongholds in the south and southeast regions of Yemen. A Yemeni group affiliated with the Islamic State, seeks to overshadow al-Qaeda. The Islamic State has begun asserting its presence in the region with its bombings that targeted Shiite mosques in Sana'a in March 2015, killing 137 Yemenis and injuring hundreds more.[141] On top of all this, a secessionist movement in Southern Yemen is gaining momentum, and has secured some support from the United Arab Emirates. The civil war in Yemen has now grown into a regional conflict with sectarian divisions driving regional powers to choose sides. Saudi Arabia and other Gulf states have backed Hadi's Sunni government while Iran is backing the Shia Houthis. The intervention of regional actors has only increased the bloodshed, further destabilized the country, and created a stalemate with no end in sight.

The civil war in Yemen is exacerbating already prominent issues of water scarcity further by cutting off access to safe drinking water in conflict-stricken areas. For example, the general director of Aden's water authority says that the number of workers at his disposal has decreased

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[136] "Yemen's Saleh Agrees to Transfer Power," *Al Jazeera*, November 24, 2011, http://www.aljazeera.com/news/middleeast/2011/11/201111235504010 1606.html.
[137] Mohammed Jamjoom, "Yemen Holds Presidential Election with One Candidate," *CNN,* February 22, 2012, https://www.cnn.com/2012/02/21/world/meast/yemen-elections/index.html.
[138] Laura Kasinof, "Requiem for Yemen's Revolution," *The Atlantic*, January 25, 2015, http://www.theatlantic.com/international/archive/2015/01/requiem-for-yemens-revolution/384808/.
[139] "Who Are the Houthis of Yemen?" *The New York Times,* January 20, 2015, http://www.nytimes.com/2015/01/21/world/middleeast/who-are-the-houthis-of-yemen.html?_r=0.
[140] Mohamed Ghobari and Mohammed Mukhashaf, "Yemen's Hadi Flees to Aden and Says He is Still President," *Reuters,* February 21, 2015, https://www.reuters.com/article/us-yemen-security/yemens-hadi-flees-to-aden-and-says-he-is-still-president-idUSKBN0LP08F20150221.
[141] Ian Black, "Yemen Suicide Bombings Leave Over 130 Dead After Mosques Targeted," *The Guardian* March 20, 2015, https://www.theguardian.com/world/2015/mar/20/isis-claims-mosque-suicide-bombing-as-its-first-atrocity-in-yemen.

precipitously, and that he does not have enough fuel to transport diesel fuel to to the city's center, since the city's pipelines were destroyed in the fighting.[142] According to Stephen O'Brien, Under-Secretary-General for Humanitarian Affairs and Emergency Relief Coordinator at the United Nations, nearly 16 million Yemenis "had no access to adequate water, sanitation, and hygiene" as of July 2017.[143]

Although verifiable data is scarce in Yemen, there have been a slew of reports on air strikes and attacks directed at desalination plants, water-bottling plants and other sites of water infrastructure—reputedly perpetrated by actors on both sides of the conflict. Both AQAP and the Houthi rebels have used water as a weapon to manipulate populations, controlling access to the scarce resource to either curry favor with constituents or punish those who oppose their rule.[144] These reports signal a willingness for key players in the country to weaponize diminishing water sources, pushing Yemen further into the arms of its ongoing humanitarian crisis.

Water scarcity and civil conflict are mutually reinforcing phenomena. While the civil war has greatly exacerbated water scarcity in Yemen, water issues predated the civil war. Though the exact magnitude of each factor's impact is indiscernible, it is clear that they are mutually reinforcing. Water scarcity, worsened by climate change, fueled civil unrest, which played a factor in prompting a civil war, which then led to the destruction of water infrastructure, worsening the water issue. This vicious cycle has had regional implications that go beyond Yemen's borders, leading to the construction of a barrier between it and Saudi Arabia.

Yemen's wealthy northern neighbor, Saudi Arabia, has taken a security-first approach to its neighbor's internal conflicts and is currently building a 1,100 mile (1770.3 km) border fence from the Red Sea to the edge of Oman to keep the conflict from crossing the international boundary.[145, 146] Saudi analysts say that their priority right now with regards to Yemen is sealing the mountainous border with a fence modeled on the one that lines its frontier with Iraq. In addition, Saudi Arabia has suspended its aid payments to Yemen, which were previously its strongest source of leverage over the country, and continues to engage in aerial bombardments on the country which have been tied to the deaths of hundreds of civilians.[147]

The instability created by the Yemeni Civil War is detrimental to U.S. foreign policy goals. In a region already plagued by conflict and volatility, the confrontation in Yemen can escalate

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[142] Iona Craig, "Seeds of Destruction: Yemen Civil War Ripping Society Apart," *Al Jazeera*, June 18, 2015, http://america.aljazeera.com/articles/2015/6/18/yemen-conflict-rips-society-apart.html.
[143] "Briefers Warn Security Council of 'Appalling' Humanitarian Situation in Yemen, as Country Faces Cholera Outbreak, Intensifying Conflict," 7999th Meeting, *United Nations Security Council*, July 12, 2017, https://www.un.org/press/en/2017/sc12908.doc.htm.
[144] Rachel Furlow, "The US Can Decide to Worsen Yemen's Water Crisis or Alleviate It," *Atlantic Council*, July 17, 2017, http://www.atlanticcouncil.org/blogs/menasource/the-us-can-decide-to-worsen-yemen-s-water-crisis-or-alleviate-it.
[145] "Saudi Arabia Builds Giant Yemen Border Fence," *BBC News,* April 9, 2013, http://www.bbc.com/news/world-middle-east-22086231.
[146] Oman is also in the process of constructing a border wall with Yemen, which together with the Saudi wall would effectively isolate the impoverished and unstable country. For more information on the Omani wall, see: Joe Gill, "'Salalah Forever': Oman's Security Wall Can't Dent Deep Yemeni Ties," *Middle East Eye*, January 30, 2018, http://www.middleeasteye.net/news/salalah-forever-yemeni-home-oman-across-troubled-border-815508113.
[147] Angus McDowall, "Saudi Arabia's New Yemen Strategy: Get Behind a Fence," *Reuters*, January 22, 2015, http://www.reuters.com/article/2015/01/22/us-yemen-security-saudi-idUSKBN0KV1VH20150122.

tensions between Saudi Arabia and Iran to dangerous levels and could potentially draw the United States into the fray. This case illustrates how addressing resource scarcity issues and climate change could allow the United States to further its foreign policy aims. While the United States interest calls for promoting stability and ending conflict, preempting war by solving collective resource governance dilemmas is the most effective kind of involvement.

Policy Recommendations

Because a strong and stable central government is a prerequisite to the successful negotiation of collective governance agreements, ending the Yemeni civil war is key to solving the water crisis affecting the country. Unfortunately, as with many conflicts in the region, the Yemeni civil war is particularly complex, is influenced by many outside actors, and holds little potential for resolution in the foreseeable future. Even in the unlikely event that the Hadi government's rule is restored, large parts of the country would remain under the control of groups who prioritize ideological agendas over governance issues such as water distribution and conservation. Yemen has taken steps both unilaterally, by creating several departments to manage its water infrastructure and resources, and multilaterally, by accepting aid from international institutions such as the World Bank and the Japan International Cooperation Agency (JICA), to mitigate its looming water crisis. However, climate change and water scarcity will continue to have detrimental effects on the social and economic stability of the country so long as civil conflict hinders putting a strong management framework in place.

An alternative to centralized state control and the resolution of the water conflict could stem from the liberalization and privatization of water distribution methods at the local level. Yemen has been devastated by conflict and the sustainability of its services undermined by neglect. Billions in investment, from both foreign and domestic sources, will be needed to rebuild the country. However, Yemen's failing economy makes large scale, domestic private investments improbable, while the abysmal security situation makes international private investments unlikely. This situation will likely remain as long as the civil war rages on. While a detailed discussion of the possible ways of resolving the civil war is beyond the scope of this monograph, it can be plausibly argued that a devolution of governmental powers combined with negotiations between Saudi Arabia and Iran must occur for stabilization. Talks towards such a resolution should undoubtedly involve the issue of water, which represents an inescapable reality for all sides of the conflict.

After a return to relative peace in Yemen, several steps are required to address the growing water scarcity crisis in Yemen. First, water access will need to be tightly regulated and controlled on a local level in order to prevent unauthorized usage. However, it is not clear who would regulate and control water access, how water access could be monitored and enforced, and how corruption and illegal extraction could be prevented. Second, physical water delivery infrastructure will need to be upgraded throughout the country to reduce inefficiencies and water waste. Third, drought resistant crops should be introduced and their usage incentivized. Finally, some have suggested investing in alternative water delivery methods such as desalination to counter the depletion of aquifers in the medium term. However, even if there was enough funding and expertise to develop desalination infrastructure in Yemen, there is little evidence that current desalination technology could make up for the depletion rate of the aquifers. Even the largest desalination plants or a

network of such facilities would struggle to produce enough fresh water just to meet the needs of the current population let alone to address depleted reservoirs and sustain water-intensive crops.

Fulfilling these steps will be challenging, risky, and require large financial capital, which Yemen's economy is unlikely to be able to sustain any time soon. It will therefore prove crucial for foreign governments and international organizations to provide the country with aid to achieve its water distribution and conservation goals, whether in terms of planning, funding or developing effective, results-based management. Regional powers and the international community must come together to determine which organizations and/or states are able to assist, what form assistance will take, how the funding will be monitored and evaluated, and how to reduce the chances of conflict in the future. However, we must consider the possibility that based on current technological capabilities and financial limitations, states such as Yemen may be beyond reasonable efforts to sustain significant human habitation and to transition to sustainable practices. Therefore, one contingency that should be given thought is the managed relocation of portions of the population to other regions. Otherwise, climate refugees from Yemen may choose to suddenly relocate *en masse* to avoid famine, which could potentially undermine the security of other states and regions.

Chapter 4: Iran and Afghanistan

The allocation and utilization of the waters of the Helmand River (or "Hirmand River" to inhabitants of the region) has been the most contentious border dispute between Iran and Afghanistan. Continued use of the river's water by both countries is vital to the population of the Sistan region, which encompasses both eastern Iran and southern Afghanistan. Iran, challenged by chronic drought and other environmental concerns—including pollution, rapid urbanization, and sandstorms—views water allocation as tightly linked to its economic security. Afghanistan similarly views water resources from the Helmand Basin as essential to its agricultural and economic development as it hopes to move forward with national development plans in the midst of decades of nearly continuous conflict.

Climate change is likely to intensify water scarcity in the Sistan region, which will both increase the pressures on the Helmand's water supplies and raise tensions over water-sharing issues between Tehran and Kabul. In the greater region, summers are expected to get hotter by two to three degrees Celsius and precipitation is projected to decline by 10 percent in the coming decades.[148] Thus, the longer this transboundary water dispute remains unresolved, the more likely conflict between the two countries becomes.

Geography and Key Actors

The Helmand River begins in the mountains west of Kabul and runs a significant length of its course through Afghanistan. The river expands in volume as it moves from its headwaters to its junction with the Arghandab River, the main tributary of the estuary system. Downstream from this junction, the river's volume dwindles as factors such as irrigation diversions, surface water evaporation and ground-water seepage take their toll.[149] The river system is fed primarily by rain and snowmelt coming from the Hindu-Kush Mountains, and drains into the Hamoun Lakes in the

[148] Somini Sengupta, "Warming, Water Crisis, Then Unrest: How Iran Fits an Alarming Pattern," *The New York Times*, January 18, 2018, https://www.nytimes.com/2018/01/18/climate/water-iran.html.
[149] Alireza Najafi and Jabbar Vatanfada, "Environmental Challenge in Trans-Boundary Waters, Case Study: Hamoon Hirmand Wetland (Iran and Afghanistan)," *International Journal of Water Resources and Arid Environments* 1 (2011): 16-24.

Sistan Basin.[150] Before emptying into the lakes, the river forms the international boundary between Iran and Afghanistan. Though the actual location of the river boundary has long been accepted by both states, disputes regarding the allocation of resources have not yet been resolved.[151]

The following figure shows the flow of water from multiple river systems located in Afghanistan into the Hamoun Lakes and the Sistan Basin in Iran. While the Sistan Basin does receive some water from local tributaries in Iran, the vast majority of the water comes from the Hindu-Kush Mountains in Afghanistan.

[150] Eelco Van Beek et al., "Limits to Agricultural Growth in the Sistan Closed Inland Delta, Iran," *Irrigation and Drainage Systems* 22 (2008): 131-143.
[151] Pirouz Mojtahed-Zadeh, *Boundary Politics and International Boundaries of Iran* (Florida: Universal Publishers, 2006).

Rivers Feeding into the Sistan

Sources: Natural Earth, Creative Commons

History of the Region and Shared Resources

The boundary between Iran and Afghanistan has been drawn by outside actors on four different occasions (three times by Great Britain and once by a Turkish arbitration commission). However, neither government has challenged the boundary since the decade before World War II.[152] Instead, both countries have remained locked in an ongoing dispute overall the allocation of the Helmand's vital waters and other riparian rights to the present day.

On August 19, 1872, the Goldsmid Arbitral Award gave equal shares of the water in the lower portions of the river basin to Afghanistan and Iran. This agreement held until the Helmand River changed course in 1896 and a severe drought in 1902, after which the two governments attempted to reach new agreements in 1905 and again in 1938. However, both efforts were unsuccessful.[153] On September 7, 1950, the two governments, with the help of the U.S. Department of State, signed the Terms of Reference of the Helmand River Delta Commission, which established the Neutral Technical Commission for the Helmand River Delta. This commission was intended to flesh out the technical methods for sharing the waters of the Helmand River.[154] The Commission drafted a report in 1951, but both Afghanistan and Iran rejected the document at the Washington Conference of 1956. In that same year, the Iranian government proposed that it be allocated 51.7 cubic meters per second, which was quickly refuted by the Afghans. It was not until 1973 that Iranian Prime Minister Amir Abbas Hoveida and Afghan Prime Minister Mohammad Musa Shafiq were able to sign an accord to delegate the water allocations.

Both countries' parliaments fiercely opposed the treaty's complexity, and its unpopularity raised questions as to its effectiveness in governing riparian allocations of the water resources. To make matters worse, major disruptions occurred in the region during that time, including the Afghan coups d'état in 1973 and 1978, the Soviet invasion of Afghanistan, the Iranian Islamic Revolution, which led to subsequent tensions between the Sunni Taliban and the Shia government in Tehran.[155] These factors severely crippled the legitimacy and effectiveness of the 1973 agreement. Since then, Iran has tried to negotiate with the Afghan government under the framework of the 1973 agreement, but these discussions have not resulted in an accord. In January 2016, an Iran-Afghanistan memorandum expressed the necessity of both countries adhering to the 1973 agreement, as well as the desire to hold regular meetings of water commissioners.[156] Yet without increased cooperation on both sides and outside assistance, the potential for conflict between the two states remains, and each country's resource security hangs in the balance.

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[152] U.S. Department of State, *Afghanistan-Iran Boundary, International Boundary Study No. 6*, Washington, D.C.: 1961.

[153] Alex Dehgan, Laura Jean Palmer-Moloney, and Mehdi Mirzaee, "Water Security and Scarcity: Potential Destabilization in Western Afghanistan and Iranian Sistan and Baluchestan Due to Transboundary Conflicts," in *Water and Post-Conflict Peace Building*, eds. Erika Weinthal, Jessica Troell, and Mikiyasu Nakayama, (New York: Earthscan, 2013): 305-326.

[154] Ibid.

[155] Dehgan et. al, "Water Security and Scarcity."

[156] Fatemeh Aman, "Iran-Afghan Differences over Helmand River Threaten Both Countries," *Atlantic Council, IranInsight*, March 17, 2016, http://www.atlanticcouncil.org/blogs/iraninsight/iran-afghan-differences-over-helmand-river-threaten-both-countries

Iran

Iran has had significant water-related concerns for much of the past century. The country suffered through a severe three-year drought from 1998 to 2001, and the UN estimated that drought-related damage to agriculture and livestock cost Iran $3.5 billion in 2000 and $2.5 billion in 2001. These droughts severely affected ten of Iran's twenty-eight provinces, leaving approximately half of the population (37 million people) vulnerable to food and water insecurity.[157]

In recent years, Iran's water problem has increased dramatically. Rapid population growth in the latter half of the twentieth century[158] has strained water resources, and left Iran unable to grow enough food to feed its population, inhibiting the government's goal of achieving food self-sufficiency. Furthermore, Iran's rapid urbanization has created overcrowded cities where water infrastructure cannot sustain large populations. Deforestation has worsened, and wetlands and bodies of fresh water have been progressively destroyed as the industrial and agricultural sectors have expanded. Climate change threatens to further decrease water availability for the country in conjunction with a growing population and mismanagement of existing resources. According to the Iranian government, the country expects to see a 25 percent decline in surface water runoff by 2030 due to declining snowpack (the origins of their rivers) and precipitation—patterns forced by global warming.[159]

Iran relies heavily on renewable water sources for its agricultural production, a sector that contributes over 11 percent to the gross national product and employs a quarter of the labor force.[160, 161] More than 90 percent of the country's renewable water resources are used for agriculture. However, due to low efficiency in irrigation and transport, 50 to 60 percent of the water is lost during the process.[162] Furthermore, recent modernization of agricultural practices has led to severe water pollution. Increased water demand for agricultural irrigation has led to an overuse of rivers and streams, thereby incentivizing farmers to pull from underground water resources, which are not sufficiently replenished by rain or snowfall.[163] Wasteful water infrastructure magnifies the need for access to limitless water resources, since Iran's agricultural sector accounts for approximately one-tenth of GDP, employs one-fifth of its workforce, and shoulders a massive social responsibility, given the country's goal of achieving food self-sufficiency.[164] Iran uses 80 percent of the Helmand's current downstream flow to support this sector of its economy. It is of little surprise then that Iran considers the Helmand's waters crucial to food security and its economic growth.

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[157] Shahram Chubin, "The Environmental Challenges in the Gulf and the Impact on Regional Security," (paper presented at a workshop on "National Security, Resource Competition and Climate Change" at Tufts University European Center, Talloires, France, May 8-11, 2014).
[158] "Population growth (annual %), Iran" *The World Bank*, https://data.worldbank.org/indicator/SP.POP.GROW?locations=IR.
[159] Sengupta, "Warming, Water Crisis, then Unrest."
[160] The Islamic Republic of Iran, Ministry of Commerce, *The Memorandum of the Foreign Trade Regime of the Islamic Republic of Iran*, 2009, https://web.archive.org/web/20130310232210/http://www.irantradelaw.com/wp-content/uploads/2010/03/Irans-Foreign-Trade-Regime-Report.pdf.
[161] "Iran Economic Structure," *Economy Watch*, June 29, 2010, http://www.economywatch.com/world_economy/iran/structure-of-economy.html
[162] Dehgan et al., "Water Security and Scarcity."
[163] Chubin, "Environmental Challenges."
[164] Dehgan et al., "Water Security and Scarcity."

Over 7 million people inhabit the Helmand River Basin and use its resources primarily for irrigation, as most of the agricultural production occurs in the lower reaches of the basin. Ninety-five percent of the Helmand Basin is located in Afghanistan, but because of a lack of proper access to groundwater, it is the only water resource for the major cities in Sistan and Baluchistan, the most isolated, marginalized, and least stable of Iran's provinces. The Sistan inland delta has a population of about 400,000 on the Iranian side, thereby making the Iranian economy immensely dependent on water resources from the Helmand River and the Hamoun wetlands for food and agricultural needs. The Helmand reservoir's primary function for Iran is as a public water supply for the cities in the eastern provinces of Iran, while the remaining water is used for irrigation. Furthermore, the four Chahnimeh reservoirs on the Helmand supply water to the river systems in times of drought, which have been continuous in the region since the 1990s.[165]

Less than ten percent of Iran's water resources originate outside the country, but regions dependent on transboundary water resources, such as Sistan and Baluchistan, are highly susceptible to water scarcity.[166] Like in Africa, urbanization, industrialization, and irrigated agriculture have increased the demand for water while simultaneously reducing the supply. These conditions put Iran increasingly on alert regarding any current and future developments that further threaten its water supply, regardless of broader potentially positive impacts on the region.

Afghanistan

After three decades of nearly continuous conflict, the Afghan government, under the leadership of President Ashraf Ghani, elected in 2014, has set upon the path towards economic recovery. The strategy for such a drastic reconstruction of the country requires harnessing all its natural resources to the maximum degree—including water. Afghan efforts to achieve economic stability include agricultural development and, therefore, intensive water withdrawal, diversion, and containment projects in the Helmand. In Afghanistan, 98 percent of the water drawn from the Helmand Basin is being used by the agricultural sector. In addition, 80 percent of the country's population is directly dependent on natural resources management, primarily in agriculture and livestock. As Dehgan et al. state in the edited volume *Water and Post-Conflict Peacebuilding*, "future agricultural development—a key portion of [former] U.S. president Barack Obama's strategy to rapidly increase economic activity—will depend on the availability of sufficient water resources for expansion."[167] Although Afghanistan's geological characteristics should provide it with sufficient water for its needs, the country lacks the infrastructure to efficiently draw on its resources. This exacerbates the water dispute, as a lack of infrastructure forces Afghanistan to continuously demand more from the shared water basin.

Water-Related Tensions between Afghanistan and Iran

Though Afghanistan's economic development could benefit Iran by reinforcing regional stability, the water consumption required by such development has diminished Iran's water supply, creating the potential for increased tension between the two countries. The Iranian government sees Afghan development tactics as damaging to water security in eastern Iran, particularly in the Sistan and Baluchistan regions, often viewed as "Iran's Achilles' heel." Sistan and Baluchistan are heavily Sunni, which has fed tensions as these regions' Sunni populations feel increasingly

[165] Ibid.
[166] Ibid.
[167] Ibid.

marginalized in a Shiite-dominated state.[168] This has caused Iran to become increasingly defensive against actions that might threaten its fragile hold on its eastern provinces. Iran views Afghanistan's construction of hydroelectric dams as a direct security threat and fears that Afghanistan's U.S.-supported development policies will deprive Iran of resources crucial to the people's well-being as well as future development plans.[169]

The dispute has intensified since the inception of the Kamal Khan Dam project, an Afghan project which began in 1996 but, due to war, was put on hold until 2011.[170] *Wadsam,* an online Afghan news portal, reported: "the dam has the capacity to produce 8.5MW of electricity and to irrigate 80,000 hectares of land."[171] When completed, the dam will severely affect the amount of water that flows into Sistan and Baluchistan. Despite Iran's involvement in Afghan reconstruction projects, since 2002 the Helmand River has been a source of tension.[172] The dispute has gradually intensified as opposing sides have publicly displayed their disapproval of one another. Iranian hardline media has accused "ungrateful" Afghans "who do not appreciate what Iran has done to help them," of violating the frail 1973 accord. The Afghan media quoted "Afghan officials" as saying that Iranian concerns are baseless and that "it is the right of Afghanistan to construct dams on its soil."[173]

Afghan efforts to harness and divert water from the watersheds without forging an agreement with Iran have inspired Iran to adopt a paradoxically mixed strategy of destabilization and cooperation with Afghanistan.[174] On the one hand, Iran has sought to support development in Afghanistan, particularly where such funding would lead to benefits for Iran, such as improved efficiency in water use and transport. On the other hand, Iran has provided support for Taliban insurgent groups in Afghanistan, which has slowed or prevented U.S. reconstruction projects, including those around the water sector, and has taken direct actions against Afghan development plans.[175] This is of particular importance because Iran has historically opposed the Taliban, a group with a long track record of hostility towards the Iranian government and Shiites generally.

Although Iran nearly went to war with Taliban-controlled Afghanistan in the late 1990s by supporting the Northern Alliance, Iran reportedly has been supporting various factions of the Taliban. In 2011, Afghan authorities captured a Taliban commander, Mullah Dadullah, in southwestern Afghanistan who claimed that he was trained in Iran and offered $50,000 to destroy the Kamal Khan Dam. Although Iran disputes this accusation, such allegations are likely to increase in the future if the dispute remains unresolved.[176] Iran has also taken direct actions to halt Afghan development projects. In March 2009, Afghan security forces found Iranian-made

[168] Ibid.
[169] Fatemah Aman, "Afghan Water Infrastructure Threatens Iran, Regional Stability," *Al Monitor*, January 7, 2013, http://www.al-monitor.com/pulse/originals/2013/01/afghanwatershortageiranpakistan.html#.
[170] Ibid.
[171] "Completion of Kamal Khan Dam in Nimroz Province," *Wadsam Afghan Business News Portal,* December 3, 2015, http://wadsam.com/afghan-business-news/completion-of-kamal-khan-dam-in-nimroz-province-232/.
[172] Ibid.
[173] Ibid.
[174] Dehgan et al., "Water Security and Scarcity."
[175] Ibid.
[176] Aman, "Afghan Water Infrastructure."

explosives and ammunition around the Bakhashabad Dam in the Farah Province, and Iran has since attempted to disrupt the dam project.[177]

Afghan activities and their threat to Iranian water supplies have caused Iran to create alliances (such as support for the Taliban) that are at once pragmatic and risky. Such actions are motivated not by religious rationales, but rather by the threat of losing water resources to Afghan development projects. Iran seems to care less about the long-term threat that the Taliban could pose to its security than the short-term benefits of using them to reduce the risk of diminishing water supplies. Iran's support for the Taliban is indicative of how a country may adopt shortsighted policies to provide basic resources to its citizens.

Climate Change as a Source of Tension

Water scarcity in Iran and Afghanistan has been affected and exacerbated by climate change; its effects will likely worsen in the coming decades. There are strong indications that climate change is increasing the rate at which glaciers in Central Asia are melting, with current data showing that Afghanistan's glaciers have shrunk by as much as 50 to 70 percent.[178] Although the melting of glaciers may increase river flow in the short term, the long-term impact of retreating glaciers will be a permanently reduced runoff.[179] Decreases in rainfall and snowfall and increases in temperature due to climate change will only intensify the changes caused by glacial melting. The Intergovernmental Panel on Climate Change suggests that water stress caused by above average temperatures and below average rainfall will continue to increase in southeast Iran and southwest Afghanistan.[180]

Water scarcity caused by drought will continue to play a significant role in shaping tensions in the region. From 1999 to 2009, the Helmand Basin region in Afghanistan and Iran experienced drought conditions that greatly increased tensions between the two countries. Drought played a key role in the displacement of people in southwestern Afghanistan. "According to the Kabul office of the United Nations High Commissioner for Refugees (UNHCR), the majority of Afghanistan's internally displaced persons—166,153 out of 235,833 individuals—were displaced for two reasons: the conflict in the period prior to and after the fall of the Taliban in 2001 and the drought of the 1990s."[181] Since then, however, it has been anticipated that the newly-formed Afghan government will demonstrate a commitment to creating a stable environment for the safe return of many of its refugees. However, many of the returned refugees have migrated to towns and cities, contributing to the country's rapid urbanization, and thereby intensifying the country's water stress.[182]

The Iranian Ministry of Agriculture announced that during the drought of the late 1990s and early 2000s, the agricultural sector, which makes up 27 percent of Iran's GNP, had suffered

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[177] Dehgan et al., "Water Security and Scarcity."
[178] Jakob Granit et al., *Regional Water Intelligence Report Central Asia: Baseline Report*, Regional Water Intelligence Report No. 15, (Sweden: United Nations Development Programme, 2010).
[179] Ibid.
[180] Dehgan, "Water Security and Scarcity."
[181] Ibid.
[182] U.N. High Commissioner for Refugees, *UNHCR Global Appeal 2015 Update*, *Afghanistan*, 2015, http://www.unhcr.org/5461e6090.pdf.

serious damage that had caused GNP to decrease by 6 percent.[183] The Taliban's decision to cut off the flow of the Helmand River to Iran in the midst of the drought from 1999 to 2001 further intensified tensions with Afghanistan and wreaked ecological havoc by degrading plant and animal habitats within the Sistan and Baluchistan provinces. As a result of natural drought and the Taliban's water policies, Iran's lakes dried up and sandstorms buried dozens of villages and destroyed farmland.[184]

The drought has had direct and indirect effects on farmers in Afghanistan and Iran. The direct effects include decreased production in agriculture and rangelands, groundwater depletion, and low river and stream flows, which expose ecosystems to destruction, contamination, soil erosion, and the deaths of livestock and wildlife. Indirectly, the drought has lowered farmers' income, decreased the government's tax income, increased the cost of water and forage transport, and increased the migration of farmers to the cities.[185] Droughts also reduce harvest size and qualities of grain, with damaging economic impacts on the agricultural sector.

Sandstorms have also played a significant role in threatening the livelihood of the region's inhabitants and their access to safe drinking water. The decreased surface water flow and availability of water in the Helmand River system indicates increased desertification. Though strong local winds occur annually, wind-generated sandstorms are longer than average during the drought years due to the drying up of the Hamoun basins, as most of the windblown dust originates from those beds. Persistent drought conditions, accompanied by increased diversion of Helmand River resources for irrigation and agriculture, have turned these wetlands into arid salt pans.[186] If dust storms in Central Asia increase in severity with continued climate change as they are expected to in the Middle East, public health and agriculture could be endangered.[187]

Failed Solutions

Despite Iran's current efforts to undermine Afghan development projects, Tehran has continuously tried to negotiate the status of the Helmand River (and other waterways) with Kabul. "Iran's official policy is to reach formal agreements and to pursue the benefits of cooperation, such as flood and drought control, political stability, and regional economic development."[188] Since 2003, Iran has established a trilateral Iran-Afghanistan-Tajikistan commission to negotiate the discharge flow of the Helmand River. However, Afghanistan has continued to thwart such attempts under the rationale that it lacks expertise, data, and capacity to participate in transboundary water negotiations. Although these deficiencies exist, Afghanistan may be using these justifications as a stalling technique, understanding that any negotiations with Iran could potentially result in a decrease in water retained by Afghanistan. On the other hand, Iran's push to come to a comprehensive agreement on water-sharing rights is indicative of its eagerness to enter into

[183] Sayed-Farhad Mousavi, "Agricultural Drought Management in Iran," in *Water Conservation, Reuse, and Recycling: Proceedings of an Iranian-American Workshop,* (Washington, DC: National Research Council Office for Central Europe and Eurasia Development, Security, and Cooperation, 2005), 106-113.
[184] "Iran Seeks its Share of Hirmand Water," *Trend*, April 15, 2011, https://en.trend.az/iran/1861694.html.
[185] Mousavi, "Agricultural Drought Management in Iran."
[186] Ibid.
[187] "Giant Middle East Dust Storm Caused by a Changing Climate, Not Human Conflict," *Princeton University*, January 13, 2017, https://www.princeton.edu/news/2017/01/13/giant-middle-east-dust-storm-caused-changing-climate-not-human-conflict.
[188] Andrew Houk, "Transboundary Water Sharing: Iran and Afghanistan," *Stimson Spotlight,* March 22, 2011. http://www.stimson.org/spotlight/transboundary-water-sharing-iran-and-afghanistan/.

binding water-sharing agreements while Afghanistan's water management capacity is low. These competing interests have obstructed the ability to address water concerns across borders and could increase tensions between the two countries or slow or prevent stabilization process in Afghanistan's western provinces.

Policy Recommendations

Peacefully resolving the tensions in the Helmand River Basin is crucial to avoid further destabilizing an already volatile region of the world. America's large investments in Afghanistan could turn out fruitless should the country experience a military conflict with a neighboring state over water rights. Controlling a disproportionate share of water resources in the Helmand River Basin would also allow Iran to gain further regional power, which would be highly detrimental to the United States' interests in the region.

In order to handle this dispute carefully, actors must first focus on domestic concerns before aiming to address international disputes. There is no doubt that both Iran and Afghanistan are in need of Helmand water sources to cater to their domestic needs. Therefore, the United States should not take sides on which country is more deserving of these rights. Already managing the challenges of refugees, unemployment, inflation, and growing populations, additional water and food scarcity would further destabilize both Iran and Afghanistan. On the other hand, greater use of water resources and increasing water management are key parts of the Afghan National Development Strategy, legitimizing their need to build hydroelectric dams and harness the waters of the Helmand River.

A study published in 2015 questioning the 1973 Helmand Treaty and its effectiveness for sustainable transboundary water resources management found that, by failing to fulfill the most basic requirements for integrated water resources management and river basin management, the treaty lacked the credibility to help balance the legitimate development in upstream Afghanistan while also limiting harm to downstream Iran.[189] To prevent a future accord from falling into the same trap, comprehensive reconstruction of both countries' water management infrastructure must precede any agreement.

As previously stated, because of low irrigation and transport efficiency, Iran wastes approximately 50 to 60 percent of its renewable water resources. Efficient water infrastructure and usage in agriculture is one of the most important contributing factors in promoting Iran's food self-sufficiency plans. Proper planning and management in the water sector would help prevent the waste of limited natural resources and would help Iran to maximize the potential of its water sources. The National Resource Council Committee on U.S.-Iranian Workshop on Water Conservation and Recycling therefore holds that the efficient usage of water in the country is one of the most important policies of the Iranian government.[190]

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[189] Vincent Thomas and Manijeh Mahmoudzadeh Varzi, "A Legal License for an Ecological Disaster: the Inadequacies of the 1973 Helmand/Hirmand Water Treaty for Sustainable Transboundary Water Resources Development," *International Journal of Water Resources Development* 31, no. 4 (2014): 499-518.

[190] Abbas Keshavarz et al., "Water Allocation and Pricing in Agriculture of Iran," in *Water Conservation, Reuse, and Recycling: Proceedings of an Iranian-American Workshop,* (Washington, DC: National Research Council, Office for Central Europe and Eurasia Development, Security, and Cooperation, 2005), 153-172.

Afghanistan also suffers from poor management and infrastructure for water resources. One of Afghanistan's greatest weaknesses in water management is its failure to legislate a comprehensive water law, as existing law does not define water rights. The lack of a database of natural resources and the limited ability of the government to collect data is a major obstacle to planning and development, making the water management infrastructure highly ineffective. In addition, there is a severe under-utilization of resources, as Afghanistan controls and utilizes only 15-30 percent of its domestic water resources.[191]

In terms of international accords, any solution must take into account the water needs of both nations and the rights and obligations imposed by international law, bilateral treaties, and state practices on the use of water from shared basins.[192] Water is necessary for Afghanistan's development and stability. However, if Afghanistan does not fairly address transboundary water issues with Iran, it will not be able to proceed with its development strategy without incurring severe damage to relations with its far more powerful neighbor. Because Afghanistan claims that it lacks the capacity and data to enter into negotiations, the United States should step in and work to increase Afghanistan's capacity at the technical level by creating monitoring systems that are transparent and building fair mechanisms for technical cooperation to the benefit of both countries.[193] Yet, since Iran will not view the United States as a neutral actor in this role, the United Nations may be more effective in promoting bilateral cooperation.

However, if it becomes clear that the Afghanistan government is unwilling to negotiate under current circumstances and is only claiming a lack of capacity to negotiate or develop data to delay negotiations until they are in a better position, then the United States must use all its levers of influence to bring the government to the table. The United States must make clear that obstruction and delay even by an ally like Afghanistan cannot be allowed to continue indefinitely if it risks embroiling the region in another conflict and put U.S. interests in jeopardy.

Water is a collective issue for Afghanistan and Iran and has serious implications for regional stability. Any solution should therefore be multilateral, and the need for international aid in facilitating cooperation should not be overlooked. However, foreign actors involved in the region, in particular U.S.-led forces, should avoid politicizing this problem, as it is already highly susceptible to historical grievances and national pride and security. National investment decisions should be based not on efforts to deprive neighboring countries of water. Instead, decisions should be advised based on avoiding waste and improving utilization of resources in accordance with the evolving scientific projections—particularly in regards to the future of freshwater runoff from a melting source glacier and the potential for surface drying from increased regional temperatures. Without regional cooperation, both Iran and Afghanistan will be faced with challenges that will become even more difficult to solve, partly due to a changing climate. These challenges will further fuel the rising tensions between them.

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[191] Aman, "Afghan Water Infrastructure."
[192] "Alternative Futures for Afghanistan and the Stability of Southwest Asia: Improving Regional Cooperation on Water*," EastWest Institute*, Symposium, Session 4: The Helmand River Basin and the Harirud and Murghab Rivers, Grimbergen, Belgium, June 25, 2009.
[193] Dehgan et al., "Water Security and Scarcity."

Chapter 5: The Indus River Dispute

Current Situation in the Indus River Basin

Water sharing is a point of serious contention on the Indian subcontinent, a landmass home to more than 21 percent of the world's population. Despite its burgeoning population, the subcontinent has access to only 8.3 percent of the world's fresh water supply.[194] Within South Asia, India is a major player in subcontinental hydro-politics, as it is the largest country and, excluding island states, shares a border with all other countries in the region. Interstate water disputes are common in this region, as many states that are upstream to the subcontinent, such as China, exploit their riparian advantage at the cost of water security for their downstream neighbor states, such as Bangladesh. However, amidst various water disputes in the region, the nearly six-decade-long dispute between India and Pakistan along the Indus River stands out as one of the most distinct and important disputes in the region. Furthermore, the Indus Water Treaty that emerged from the water disputes has become one of the few points of bilateral cooperation between them. The worsening effects of climate change are likely to threaten the fragile Indian-Pakistani cooperation that currently exists. If competition over scarce water resources leads to an overall breakdown in bilateral cooperation, both nations' security and wellbeing will be negatively affected.

Both states are crucial in ensuring the United States' continued presence and influence in the regions of the greater Middle East and South Asia. Though India will be a key economic partner and could allow the United States to retain a powerful ally in a region increasingly economically dominated by China, Pakistan remains an important, if ambiguous, ally in the "War on Terror." Any escalation of the confrontation over the allocation of Indus River Basin water would weaken both countries and constrain the United States' ability to project influence in the region.

[194] Brahma Chellaney, *Water: Asia's New Battleground*, (Washington, D.C., Georgetown University Press: 2011).

Geography and Key Players

The Indus is located in Northwest India and Pakistan. The transboundary Indus River Basin has a total area of 1.12 million square kilometers, which is divided between Pakistan (47 percent of territorial control), India (39 percent), China (8 percent), and Afghanistan (6 percent). The main actors in this basin, however, are India and Pakistan. The primary river, the Indus, is about 3,218.68 km (2,000 miles) long, and its major tributaries from the west, the Kabul and the Kurram, together are more than 321.87 km (200 miles) long. The main tributary to the east is the Panjnad, which includes the Jhelum, Chenab, Ravi, Beas, and Sutlej. Together, their aggregate length is over 2,800 miles.[195] The Indus River stretches from the Himalayan Mountains in the north to the southern provinces in Pakistan, and deposits into a delta where the river meets the Arabian Sea. The river flows draw from glacier melt, snowmelt, rainfall, and runoff.[196] Due to the vast number of tributaries and sheer stretch of the river, the Indus River system has been vital to those in the subcontinent since the dawn of civilization.

The following figure shows the Indus Basin. In 1960, India and Pakistan signed a treaty to share the flow of water from the multiple rivers that run through the Indus Basin. While the Indus River originates in China, it is not part of the 1960 Indus Water Treaty.

[195] Salman M. A. Salman and Kishor Uprety, *Conflict and Cooperation on South Asia's International Rivers: A Legal Perspective,* ed. Rudolf V. Van Puymbroeck (Washington, D.C.: The World Bank: Law, Justice, and Development Series, 2002).
[196] "Indus River Basin," in *Irrigation in Southern and Eastern Asia in Figures – AQUASTAT Survey* ed. Karen Frenken (Rome: United Nations Food and Agriculture Organization, 2011).

Indus Water Treaty, 1960

Source: Natural Earth

Historical Political Rivalry

The rivalry between India and Pakistan has its roots in both religious antagonism and the political struggle to gain independence from the British Empire in the mid-twentieth century. The hasty British partition of the Indian sub-continent, carving Pakistan out of what was then India in 1947, transformed what had been an ethno-religious dispute into one among sovereign, independent states. Land disputes over Kashmir, in the most northern region of the Indian subcontinent, have been a focal point in the two states' highly adversarial relationship.[197] Amidst these tensions lies the issue of the Indus River waters. The dispute became an international issue with the partition of the Punjab region into Indian East Punjab in and Pakistani West Punjab. The fact that the British-drawn boundary between the two countries ran straight through the Indus Basin made matters worse. This gave India control of five of the six rivers in the Indus system due to its upstream position, and left Pakistan with only one. Moreover, two important irrigation headworks, on which two irrigation canals in Pakistan's West Punjab had been completely dependent for their supplies, were left in India's possession. The partitioning of the water basin, therefore, left Pakistan heavily dependent upon canals controlled by India.

Irrigation is essential for agriculture in the basin's semi-arid climate. Large seasonal and annual variability in the river system's water volume reinforces this.[198] Given the uneven division of the water irrigation infrastructure, India has the ability to cut off vital irrigation water from Pakistan. It has further claimed the right to use the waters from all six rivers without interference.

To ameliorate emerging water disputes and lack of codified water allocation rights, engineers of East Punjab and West Punjab signed a Standstill Agreement on December 20, 1947, scheduled to expire March 31, 1948. The authorities in East Punjab refused to renew the agreement on April 1, and on that day, India cut off water flow to Pakistani canals, whose water supplies originated from the rivers Ravi and Sutlej.[199] India undertook this mission in the hopes of asserting its right to the waters of three eastern rivers (Ravi, Beas and Sutlej). This caused a serious setback to the Pakistani national economy by stymying agricultural production. This state of affairs greatly epitomizes the high importance that Pakistan has given to resolving water disputes with India since its foundation in 1947.[200]

Pakistan could have declared war, as many Pakistani officials advocated. However, the leadership of the newly-formed Pakistani state foresaw that a war with India would likely not end in Pakistan's favor, so Islamabad opted for negotiations and sent delegates to New Delhi to discuss the restoration of its water canals. Following extensive negotiations in a conference between the two states, the New Delhi Agreement was signed on May 4, 1948. "Under the terms of that agreement, East and West Punjab recognized the necessity to resolve the issues in the spirit of goodwill and friendship."[201] Resulting from this agreement, the Indian government assured Pakistan that it would not suddenly withhold the water supply again without providing sufficient time for Pakistan to develop alternate sources.

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[197] Undala Z. Alam, "Questioning the Water Wars Rationale: A Case Study of the Indus Waters Treaty," *The Geographical Journal* 168 (December 2002): 341-353.
[198] Ibid.
[199] Salman, *Conflict and Cooperation.*
[200] "Indus River Basin," *United Nations Food and Agriculture Organization*.
[201] Salman, *Conflict and Cooperation.*

This agreement was later renounced by Pakistan in 1950, and it wasn't until 1952 that India and Pakistan welcomed World Bank mediation. The World Bank proposed a comprehensive plan for the joint development of shared water resources, but the plan failed to take into consideration the sensitive political and religious issues underlying the deep animosity between the two parties. Although the World Bank expected the two sides to come to an agreement on water allocation, neither India nor Pakistan seemed willing to budge.[202]

After nearly eight years, the World Bank finally brokered an agreement between both parties, the Indus Water Treaty of 1960. The treaty acknowledged that both India and Pakistan have an interest in the optimum development of the rivers and provides for cooperation and collaboration between the two countries.

The water-sharing agreements under the treaty instituted some important changes in the Indus Basin. Under Article II, India secured unrestricted use of all the waters in the eastern rivers of the Indus system, including the Ravi, Beas, and Sutlej.[203] India was also subject to a ten-year transition period to allow a specified amount of water to Pakistan, while Pakistan was carrying out the necessary construction of works on its allocated rivers to replace its eastern river sources. Under Article III, Pakistan was awarded unrestricted use for all the western rivers, including the Jhelum, Chenab, and Indus, subject to the right of India to use some of the water for irrigation, the generation of hydroelectric power, and other legitimate purposes before the rivers cross into Pakistan.[204, 205]

While this treaty represents one of the major achievements of the international system because external involvement effectively decreased bilateral tensions, it failed in its purpose in several regards. Initially, this treaty helped reduce tensions between the two countries and allowed Pakistan to jump-start the Indus Basin Project, the construction of a network of canals and dams to divert waters from the western rivers to aid Pakistan's domestic development projects in the 1960s. However, since its signing, the Indus Water Treaty has become a contentious issue as political rivalries persist between the two states. India's 2008 Baglihar Dam, on the Chenab River in the state of Jammu and Kashmir (which both Pakistan and India claim), has been a source of continuing disputes between India and Pakistan.[206] After India began its construction in 1999, Pakistan claimed that the design parameters of the dam violated the Indus Water Treaty, an accusation that the World Bank rejected. The dispute between Pakistan and India over the Baglihar Dam is another manifestation of the conflict over Kashmir and is creating additional strain on bilateral relations.

Another unresolved dispute between India and Pakistan is over the Tulbul Navigation Project (called the Wular Barrage Project by Pakistan), an Indian plan to divert water on the Jhelum River. India has argued over Pakistani objections that this dam would raise water levels to allow river transit in the summer season. Formally, Pakistan denies the project on the grounds that it

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[202] Ibid.
[203] *The Indus Waters Treaty 1960*, September 19, 1960, https://siteresources.worldbank.org/INTSOUTHASIA/Resources/223497-1105737253588/IndusWatersTreaty1960.pdf.
[204] Ibid.
[205] Salman, *Conflict and Cooperation.*
[206] "Indus River Basin," United Nations Food and Agriculture Organization.

involves water storage on a river that belongs to Pakistan, making it a violation of the treaty; informally, Pakistan believes that it could be used as a geo-strategic weapon to divert the river's flow away from Pakistan. In response, India argues that the plans do not include creating storage and that the proposed dam will merely block the waters temporarily, slowing the rapid depletion of floodwater to extend the period of navigable conditions. India further claims that this development would even benefit Pakistan, as navigable waters allow more opportunity for transportation and security. However, even under the framework of the 1960 treaty, inter-governmental talks on the subject have yet to prove successful thus far.[207]

The water dispute between India and Pakistan is complex and potentially dangerous not only because of the technical aspects of water management and allocation, but also due to the political rivalry between the two countries. Despite instances of disputes along the way, the Indus Treaty has served as a notable source of cooperation between two countries whose historical animosity continues to undermine the adoption of integrated water cooperation.

Dependence on the Indus River

Pakistan's geography makes it completely dependent on the Indus Basin for its agricultural and municipal water usage. Unlike India, which has access to several river systems, including the Ganges and the Cauvery rivers, Pakistan has only the waters from the Indus Basin. The Indus River waters over 80 percent of Pakistan's irrigated land. Agriculture accounts for 21 percent of the country's GDP and is a cornerstone of the Pakistani economy, making access to the Indus River waters critical for a sustained agricultural sector and a stable economy.[208]

Pakistan continues to face chronic issues of resource mismanagement and endemic structural inefficiencies, as a combination of fuel and energy shortages and growing water scarcity put additional strains on its citizens.[209] Abnormal fluctuations in river flows and simultaneous increases in demand only compound these concerns. Pakistan's Minister for Water and Energy, Khawaja Muhammad Asif, maintains that a combination of climate change and local waste and mismanagement has depleted Pakistan's water supply at an alarming rate. In a 2015 interview for the *New York Times*, Asif remarked: "under the present situation, in the next six to seven years, Pakistan can become a water starved country."[210] In a report published in 2013, the Asian Development Bank described Pakistan as one of the most "water-stressed" countries in the world, with a water availability of 1,000 cubic meters per person per year.[211] The stakes are high for Pakistan, as they are largely dependent on the Indus River system. According to the Asian Development Bank, Pakistan must improve its management, storage, and pricing of water for irrigation in order to meet its major challenge of boosting agricultural productivity, strengthening food security, and growing the Pakistani economy.

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[207] Roshni Chakraborty and Sadia Nasir, "Indus Basin Treaty: Its Relevance to Indo-Pak Relations," *Pakistan Horizon* 55 (October 2002): 53-62.
[208] "South Asia's Water: Unquenchable Thirst," *The Economist*, November 19, 2011, http://www.economist.com/node/21538687.
[209] Dr. M. Asif, "The Energy Crisis," *Dawn*, April 14, 2017, https://www.dawn.com/news/1326795.
[210] Salman Masood, "Starved for Energy, Pakistan Braces for a Water Crisis," *The New York Times,* February 12, 2015, http://www.nytimes.com/2015/02/13/world/asia/pakistan-braces-for-major-water-shortages.html?_r=0.
[211] "Pakistan," in *Asian Development Outlook 2013: Asia's Energy Challenge,* (Asian Development Bank, April 2013) 203-208.

The total water resource base for India, including both surface and groundwater, is substantial but highly variable. Fifty percent of annual precipitation falls in less than one month during Monsoon season, and 90 percent of river flows occur during only four months. The capacity of the current water management infrastructure to buffer that variability is low, making it difficult for supply to meet the projected demand.[212] Under the Indus River Treaty, 79 percent of the total volume of the Indus' waters was made available to Pakistan, whereas the eastern rivers allocated to India totaled only 21 percent.[213] The result has been a 52 percent deficit between water supply and demand in India's part of the Indus Basin region.[214]

Impact of Climate Change

Given the conditions of both countries, both India and Pakistan need maximum access to water resources to meet energy needs, maintain food security, and keep their domestic economies healthy. This is becoming increasingly difficult as the effects of climate change on the Indus system become more and more obvious.

The Indus Basin is already suffering from severe water scarcity due to Pakistani and Indian over-extraction for agriculture. In 1995, the Indus River supplied much less water per person than the minimum amount recommended by the United Nations, and by 2025, its water is predicted to become even scarcer.[215] Yet beyond the issue of resource overuse is the looming threat of climate change. The Indus River is extremely susceptible to climate change because a high proportion of its water originates from glacial melt in the Tibetan Plateau. Glacial melt is quite sensitive to changing temperatures. Though rising global temperatures can increase river flow by speeding up the rate of glacier melt in the near term, the long-term impact of shrinking glaciers is permanently reduced runoff. Communities that depend on the Indus will therefore face more severe water shortages, variability in precipitation, and potentially greater flooding.[216]

Policy Implications

As climate change predictions are beginning to come to fruition, the sustainable and efficient usage of the Indus River's water resources will be a critical tool in fighting water scarcity in the region. Thus, in order to thwart any potential disputes over access to water resources, both countries must work to improve domestic water management infrastructure and to mitigate the effects of climate change.

As the struggle over water resources is seated in deeper divisions between India and Pakistan, the two countries must expand their cooperation under the treaty to the political and cultural relations between the countries for any substantial water cooperation in the near future. The complexity surrounding issues such as the governance of Kashmir make them unlikely to be solved in the near term, but progress on sharing water resources could help create a political

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[212] "Charting Our Water Future: Economic Frameworks to Inform Decision-Making, *2030 Water Resources Group*, November 2009, https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/charting-our-water-future.
[213] Salman, *Conflict and Cooperation.*
[214] Chellaney, *Water: Asia's New Battleground.*
[215] "The Threat of Climate Change to the Indus," *World Wildlife Fund*, 2017, http://wwf.panda.org/about_our_earth/about_freshwater/freshwater_problems/river_decline/10_rivers_risk/indus/indus_threats/.
[216] Ibid.

environment that is more conducive to negotiations on other topics. It is important for both countries to realize that issues of water management will be mutually problematic if left unsolved and that larger disputes should be temporarily put aside for the purpose of negotiating mutually-beneficial water-sharing agreements. In the event of unfavorable political headwinds, holding such negotiations in a confidential setting and with the assistance of international organizations might prove beneficial.

Chapter 6: Fresh Water and the Nile Basin

In a January 2001 speech, former United Nations Secretary General Kofi Annan said, "Unsustainable practices are woven deeply into the fabric of modern life. Land degradation threatens food security. Forest destruction threatens biodiversity. Water pollution threatens public health, and fierce competition for fresh water may well become a source of conflicts and wars in the future."[217] This statement is particularly relevant to the situation in the Nile River Basin today. The increasing pressures of population growth, urban development, climate change, electrical inefficiencies, and a greater need for agricultural development are leading to serious regional disputes. Egypt has always been the primary benefactor of the Nile's waters and has been entirely dependent on the river for survival. However, the countries that share the Nile are no longer willing to bow to Egyptian claims in the face of increasing demands from their own people. The specific threat of saltwater intrusion from the sea into the Nile Delta primarily affects Egypt and is covered in Part II.

Given that many countries with stakes in the Nile are relatively poor, politically unstable, and suffer from resource insecurity, there emerge several potential sources of conflict. Due to the growth of populations along the Nile Basin and rising demand for more food and economic development, there is an ever-increasing need for Nile water. By 2025 the Nile River Basin will be one of the world's most populous river basin regions, as indicated by the population trends of the three main players—Egypt, Ethiopia, and Sudan. According to the U.S. Census Bureau, Ethiopia is projected to have a population of 131,261,566 (ranked tenth among all countries), Egypt a population of 115,502,146 (ranked fourteenth), and Sudan a population of 42,733,103 (ranked thirty-fourth) by 2025.[218] Similarly, the World Bank states that Egypt has a population growth rate of 2.0 percent, Ethiopia of 2.5 percent, and Sudan of 2.4 percent, in comparison to the

[217] Kofi Annan, "United Nations Secretary-General Kofi Annan Addresses the 97th Annual Meeting of the Association of American Geographers," transcript of speech, *Association of American Geographers*, March 1, 2001, https://iguwater.wordpress.com/news/speech-of-mr-kofi-annan-general-secretary-of-the-united-nations-during-the-97th-meeting-of-the-association-of-american-geographers/.
[218] U.S. Census Bureau, *International Programs - Country Rankings*, August 2017, https://www.census.gov/data-tools/demo/idb/informationGateway.ph.

U.S. population growth rate of just 0.7 percent.[219] For additional perspective, Ethiopia's rapid population growth over the past decade has led it to become "water stressed," despite its relatively abundant indigenous water resources.[220]

Furthermore, although there is concern about reduced availability of drinking water for people in water-scarce regions, agriculture still dominates water use. For example, "each day, a person drinks 2–4 liters of water but eats food that requires 2,000–5,000 liters of water in its production. Hence, the amount of water needed for agricultural production is vast."[221]

There is also increasing demand for Nile waters because of electricity deficiencies. According to the *Economist*, "Africa accounts for over a sixth [or 17%] of the world's population, but generates only 4% of global electricity."[222] Power stations are severely lacking and many are forced to use outdated generators to supply power. Because most of Africa is experiencing steady growth rates, countries of the continent must find ways to supply electricity or lose out on economic development. According to the World Bank, about 600 million people—two-thirds of the population—and more than 10 million micro-enterprises across Africa have no access to electricity.[223, 224]

The most potential lies in hydropower, which can be generated by rivers such as the Congo and the Nile, but requires dams to harness the moving water's energy. The construction of Egypt's Aswan High Dam, completed in 1970, spurred Ethiopia and other countries to take similar steps to provide hydropower for their own populations. The need for electricity and development may force countries to embark on new projects without considering the potential consequences both domestically and for those downstream. Climate change will also negatively affect Africa's potential for hydropower production. According to a 1998 Intergovernmental Panel on Climate Change (IPCC) report, "the Nile River experienced reductions in runoff of 20% between 1972 and 1987," resulting in significant disruptions in the generation of electricity via hydropower.[225] Likewise, a 1995 study by Reibsame et al. concluded that "the Nile was the most susceptible to climate change in terms of its potential for hydropower production."[226]

A major source of potential conflict is the Grand Ethiopian Renaissance Dam (GERD), a $4.8 billion initiative undertaken by the Ethiopian government to create the largest hydroelectric

[219] Population Growth (annual %), *The World Bank*, https://data.worldbank.org/indicator/SP.POP.GROW.
[220] U.S. Agency for International Development, *Ethiopia – Water*, March 23, 2018, https://www.usaid.gov/ethiopia/water-and-sanitation.
[221] Anja Kristina Martens, "Impacts of Global Change on the Nile Basin Options for Hydropolitical Reform in Egypt and Ethiopia," *International Food Policy Research Institute*, 2011, http://www.ifpri.org/sites/default/files/publications/ifpridp01052.pdf.
[222] "Electricity in Africa: The Dark Continent," *The Economist*, 2007, accessed January 23, 2013, www.economist.com/node/9660077.
[223] Makhtar Diop, "Powering up Africa's Renewable Energy Revolution," *The World Bank*, August 3, 2014, http://blogs.worldbank.org/nasikiliza/powering-africa-s-renewable-energy-revolution.
[224] "Lighting Africa Program Awards Innovative Solutions," *The World Bank*, December 5, 2012, http://www.worldbank.org/en/news/feature/2012/12/05/lighting-africa-program-awards-innovative-solutions.
[225] Tazebe Beyene, Dennis Lettenmaier, and Pavel Kabat, "Hydrologic Impacts of Climate Change on the Nile River Basin: Implications of the 2007 IPCC Climate Scenarios," *The University of Texas at Austin*, 2007, https://pdfs.semanticscholar.org/21dd/afd7072825a57cce28a7c777b8ea8c4880ea.pdf.
[226] Ibid.

power plant and reservoir in Africa.[227] As Ethiopia is located at the head of the Blue Nile, any dam system that it builds would potentially give Ethiopia control over the vast majority of the water that flows to Egypt, which originates from the Blue Nile. As a result, Egypt is extremely wary of this endeavor, while Ethiopia has clear incentives for finishing the project. Ethiopia's water demand for drinking, sanitation, and agriculture is increasing alongside its demand for electricity and concurrent with its rapid population growth. The Ethiopian government hopes to rectify these problems with the dam, which will produce over 6,000 megawatts of electricity and give the country more control over its water resources.[228]

This has led the two countries to heated disagreements over the other's rights to the Nile's water, and filling the dam's 74 billion cubic meter reservoir has become a particularly worrisome sticking point for Egypt. Cairo is concerned that the size of this reservoir would likely greatly reduce the flow of water to Egypt and Sudan for several years, and could even permanently alter the amount of water those countries are able to draw from the river. According to a study by an agriculture professor at Cairo University, Egypt could lose up to 17 percent of its farmland if the reservoir is filled in six years, but 51 percent if it is completed in three years.[229] Yet regardless of the exact time needed to fill the reservoir, Egyptian farmland will likely face adverse consequences from the concurrent reduction in water flow, creating problems for a country which employs a quarter of its population in the agricultural sector.[230] Another concern is that all this water pooled in the reservoir will be in danger of large evaporation losses. Finally, the dam will retain silt, which is important for the natural replenishment of nutrients that the river supplies to surrounding agriculture. Besides the risks to the environment and the livelihoods of the Egyptian and Sudanese populations, there is an enduring risk of increased tensions between the three countries.

All the aforementioned conditions coincide with urban development. With a growing population, there is a need for greater agricultural productivity to feed people, which requires access to large quantities of fresh water. A growing population, especially in societies with an emergent middle-class, needs food to satisfy the demands of consumers above the subsistence level, as well as electricity, housing, and other basic provisions. This often creates pressure for greater urban development to fulfill the needs of the population, but effective sanitation, filtration, and sewage systems must be in place to account for this stark urban growth. Without such systems, the water that supports this whole process will be polluted, as it already is in many African countries. Thus, an important nexus evolves with water at its heart.

Climate change is increasing the severity and complexity of the situation. "The near certainty of increased future water demand in the Nile Basin contrasts with the uncertainty of climatically-induced changes in the water supply of the Nile River Basin, both as to magnitude

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[227] "Egypt and Ethiopia Clash Over Huge River Nile Dam," *Financial Times*, December 26, 2017, https://www.ft.com/content/58f66390-dfda-11e7-a8a4-0a1e63a52f9c.
[228] Abdi Latif Dahir, "A Major Geopolitical Crisis is Set to Erupt Over Who Controls the World's Longest River," *Quartz*, January 17, 2018, https://qz.com/1181318/ethiopia-egypt-sudan-and-eritrea-tensions-over-grand-ethiopian-renaissance-dam-on-nile-river/.
[229] Maggie Michael, "Existing Only From the Nile, Egypt Fears Disaster From a Dam," *Associated Press*, October 2, 2017, https://apnews.com/046e3b91cd394690a685761c3da6f2ed.
[230] Ibid.

and direction."[231] Nile River Basin states have yet to develop the necessary policies and infrastructure that are required to adapt to climate change. The lack of regional cooperation towards greater resilience, sustainability, and adaptability will likely result in more severe floods, longer and more severe droughts, and persistent electrical outages.

As a result, Nile Basin states, and especially Egypt, will likely face a decrease in water supply simultaneously with an increase in demand. On the one hand, the decline in the supply of fresh water is primarily due to climate change, the growth in hydroelectric power development, water-intensive agriculture, and industrial development. On the other hand, the heightened demand for fresh water is primarily due to expanding populations, which require greater agricultural production and economic development. The problems of decreasing supply and increasing demand for fresh water are interconnected, overlapping, and regional in scope. Therefore, attempts to manage this issue will only be effective if they are coordinated at the regional level and address both issues of supply and demand in a comprehensive and cooperative manner.

A 2010 modeling study published in *Climatic Change* found that while Nile streamflow will likely increase due to higher precipitation over the entire basin between 2010 and 2039, by 2040 precipitation will decrease and evaporation will increase—reducing streamflow significantly.[232] Likewise, the 2001 IPCC report concluded that the "Nile Basin will experience decreases in precipitation ranging as low as zero and as high as forty percent by the end of the 21st century."[233] This coincides with reports that climate change is set to significantly increase average temperatures in African countries, leading to faster evaporation rates from Africa's reservoirs and lakes, including from the Nile River Basin. Again, the IPCC has painted a bleak picture for Africa, assessing in 2007 "that temperatures will increase by up to 5.8ºC by the end of the century in arid or semi-arid areas that are prevalent in Africa."[234]

Land purchases by foreign states are also putting additional pressures on the Nile Basin region. Although a lack of transparency makes it difficult to reliably estimate the amount of land changing hands in Africa, numerous countries, including South Korea, Saudi Arabia, and China, are reportedly purchasing arable land to make up for a domestic shortfall—a trend that has supposedly been increasing for over a decade.[235] Reports on the Nile Basin have claimed that South Korea has purchased 1.7 million acres of Sudanese land, and Saudi Arabia has leased 25,000 acres in Ethiopia.[236] While these countries plan to use this land to feed their own people, and foreign investment is usually considered to be a benefit for developing nations, it is creating problems for the African people.

Foreign investors promise better technologies and jobs for the local population, but in reality, many choose their own labor force over local workers, do not share their expertise by

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[231] Andrews-Speed, et al., "Want, Waste or War?"
[232] Beyene, "Hydrologic Impacts of Climate Change on the Nile River Basin."
[233] Ibid.
[234] Ibid.
[235] Michael Wilkerson, "Why Is Saudi Arabia Buying up African Farmland?," *Foreign Policy*, July 15, 2009, http://foreignpolicy.com/2009/07/15/why-is-saudi-arabia-buying-up-african-farmland/.
[236] Lester R. Brown, "Egypt's Food Supply in Danger," *The New York Times*, June 01, 2011, https://www.nytimes.com/2011/06/02/opinion/02Brown.html.

training the local populace, and in developing countries, as many as two-thirds "expect to sell their harvests elsewhere."[237] By reducing the agricultural products that are available for domestic consumption and extracting limited freshwater resources, these external factors could exacerbate environmental and demographic challenges among Nile River Basin countries. Additionally, if this trend continues in the Nile River Basin, the existing balance of power over riparian resources could shift.

Another threat to the peaceful sharing of the Nile's waters is the civil war in South Sudan. Spillover from this new conflict threatens to reignite historic tensions with Sudan, from which the South separated from following an independence referendum in 2011. Due to disputes over the development of oil resources between the two countries, the South Sudanese government has been unable to capitalize on its abundant energy resources, and ethnic infighting has undermined the state's stability.

Although famine and drought has plagued much of central Africa since 2011, these problems have been particularly pronounced in South Sudan due to its underdevelopment. The drought has led to an economic and agricultural collapse, which exacerbated ongoing violence and displaced large amounts of the population both inside and outside of the country. By February 2018, the civil war had displaced millions of people; more than 1 million South Sudanese are refugees in Uganda, while 767,425 reside in Sudan, 428,928 in Ethiopia, 113,039 in Kenya, and 90,003 in the Democratic Republic of the Congo.[238]

Further conflict could emerge from South Sudan's plans to develop a large agricultural sector to take advantage of its water resources and put off the construction of the Jonglei canal, an irrigation project intended to bring water from the rich wetlands of southern Sudan downstream to Sudan and Egypt. Now that South Sudan is independent, it is logical that it would prefer to keep its water resources, especially since subsistence agriculture provides a living for about 85 percent of the population.[239] Sudan and South Sudan remain locked in a dispute over the allocation of freshwater resources from the White Nile River, inhibiting their capacity to efficiently share scarce water resources. Since Sudan has sided with Egypt in this Nile dispute, South Sudan has sought to side with Ethiopia. In 2013, South Sudan expressed its opposition to the foundational 1959 Nile Water agreements between Sudan and Egypt, and is on its way to joining the Cooperative Framework agreement with Ethiopia, Kenya, Uganda, Rwanda, Tanzania, and Burundi.[240]

Although it is the most powerful country in this dispute, Egypt has been distracted by political instability at home. From 2011 to late 2013, Egypt experienced a revolution, an election, a coup d'état, and a severe crackdown on political opposition. The primary causes of the Egyptian revolution were the repressive tactics of the police, the corruption and favoritism in employment by the regime, and significant increases in prices for food staples such as wheat. Egypt has a history

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[237] Michael Kugelman, "The Global Farmland Rush," *The New York Times*, February 5, 2013, www.nytimes.com/2013/02/06/opinion/the-global-farmland-rush.html?ref=opinion.
[238] "Refugees and Asylum-Seekers from South Sudan – Total," *United Nations High Commissioner for Refugees*, March 15, 2018, http://data2.unhcr.org/en/situations/southsudan.
[239] "South Sudan." *The International Fertilizer Development Center*, https://ifdc.org/south-sudan/.
[240] Machel Amos, "Juba Rebuffs Cairo on Nile Waters Agreements," *Africa Review*, March 20, 2013, www.africareview.com/News/Juba-rebuffs-Cairo-on-Nile-waters-agreements/-/979180/1725630/-/40dvaw/-/index.html.

of social unrest caused by major fluctuations in food prices. Riots killed 800 people in 1977 after President Anwar Sadat succumbed to pressure from the World Bank to cut food subsides. In 2008, skyrocketing wheat prices caused bread riots throughout Egypt; the government addressed the issue by expanding subsidy programs to stabilize food prices. In 2010, a major drought in Russia led to export restrictions on wheat which caused global prices to soar once again. This time, the Egyptian government was not willing to provide subsidies and grain prices rose 30 percent in Egypt over the next year.[241] While the increase in food prices may not have been the only, or even primary, cause of the Egyptian revolution, it was undoubtedly a major contributing factor.

Mubarak was forced to step down and was eventually replaced by Muhammad Morsi, a former member of Muslim Brotherhood leadership, following democratic elections. However, Morsi's illiberal political tactics galvanized opposition against him and he was overthrown in a military coup. Field Marshal Al-Sisi seized power in the coup against Morsi and has since provided a fragile stability based on repression and the elimination of all political opposition. Thus, years of political upheaval, have undermined the Egyptian government's efforts to address the Nile dispute with Ethiopia and other Nile Basin states.

A final source of concern is environmental migration, which affects the whole African continent, but especially the countries of the Nile River Basin. In 2012, the Center for American Progress defined "climate migrants" as "people displaced by either the slow or sudden onset of the effects of climate change," and noted that up to 20 million people were displaced in 2008 alone due to sea level rise, desertification, and flooding.[242] According to the UN Human Rights Office of the High Commissioner, since 2008, 22.5 million people have been displaced annually by "climate-related disasters."[243] This figure includes people displaced by rising sea levels, floods, or drought, or simply those in search of water and fertile ground for either their animals or agriculture. Yet, when people migrate they are at risk of encroaching on the territory of others, which can lead to social strife.

In 2013, the International Organization for Migration reported that approximately one billion people are migrants, and nearly three quarters of those people are internally displaced;[244] a significant percentage of those internally displaced persons are on the move as a result of climate change and environmental factors.[245] Although there is no consensus estimate of how many people will be internally displaced in the next several decades, most would agree that as the effects of

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[241] Joshua Keating, "A Revolution Marches on Its Stomach," *Slate*, April 8, 2014, http://www.slate.com/articles/health_and_science/feed_the_world/2014/04/food_riots_and_revolution_grain_prices_predict_political_instability.html.

[242] Michael Werz and Laura Conley, "Climate Change, Migration, and Conflict: Addressing Complex Crisis Scenarios in the 21st Century," *Center for American Progress*, January 3, 2012, www.americanprogress.org/issues/security/report/2012/01/03/10857/climate-change-migration-and-conflict/.

[243] "U.N. Human Rights Council, High Commissioner for Human Rights, *Summary of the Panel Discussion on Human Rights, Climate Change, Migrants and Persons Displaced Across International Borders*, November 14, 2017, http://www.ohchr.org/Documents/Issues/ClimateChange/ClimateChangeMigration/A_HRC_37_35.pdf.

[244] Davide Mosca, Barbara Rijks, and Croline Schultz, "Health in the Post-2015 Development Agenda: The Importance of Migrants' Health for Sustainable and Equitable Development," in *Migration and the United Nations Post-2015 Development Agenda*, ed. Frank Laczko and Lars Johan Lonnback (Geneva: International Organization for Migration, 2013), 93-106, http://publications.iom.int/system/files/pdf/migration_and_the_un_post2015_agenda.pdf.

[245] Werz, "Climate Change, Migration, and Conflict."

climate change worsen, the number of climate migrants will increase too.

There are some areas in the Nile River Basin where the connection between climate change, migration, and conflict will come into play. For example, it has been historically customary for Sudanese nomadic communities to migrate into the rich wetlands of the south with their cattle during certain months of the year. Yet now that Sudan and South Sudan are separate countries, this migration will face complications. According to USAID, "traditional livestock migration patterns into South Sudan during the dry season will remain restricted for herders in many parts of Sudan," and some herders in the Blue Nile region will forgo migration due to the heightened risk of cross-border conflict. This adjustment will result in a reduced productivity for these herders' livestock, and therefore decreased revenues for the herders.[246]

Access to water and land in the western Sudanese region of Darfur has been a major factor in the region's long-running conflict. Drought and desertification in North Darfur led Arab nomads to migrate into South Darfur in the 1980s and 1990s, where they clashed with black African farmers.[247] Given that such conditions are likely to reoccur in this region and elsewhere, it is apparent that climate change could cause similar conflicts in the future.

The Key Players

There are three key players in the Nile crisis: Ethiopia, Egypt, and Sudan. Of the three, Egypt relies most on the Nile, but only Egypt and Sudan have long-standing bilateral agreements that give them rights to the Nile's waters. However, these agreements were written when Africa was under colonial rule, and it did not take into consideration the rights or needs of other riparian Nile Basin states. Ethiopia, which contests the legitimacy of these previous water allocation agreements, does not formally belong to any such treaties, but it does control Lake Tana, the source of the Blue Nile, the larger of the Nile's two branches that meet in Khartoum. In theory, Ethiopia could decide to significantly reduce Egypt's freshwater supply by building a series of dams to take control of the river. Egypt is much more concerned with protecting the flow of water from the Blue Nile than the White Nile since it provides significantly more water to the lower Nile River. The other riparian states that are sources for the White Nile are South Sudan, Uganda, Kenya, Tanzania, the Democratic Republic of Congo, Rwanda, Burundi, and Eritrea (an observer state to the Nile Basin Initiative). The White Nile originates in Uganda and the fertile basin it provides affects all of these countries. While these states may not rely as heavily on the Blue Nile as Ethiopia and Egypt, they still have an important stake in its future.

In the years to come, the Nile Basin states, and especially Egypt, will have a daunting challenge ahead of them. Access to fresh water along the lower Nile will likely decrease due to both climate change and rapidly expanding hydropower development up river. At the same time, greater demand across nearly all Nile Basin states will put the survival of downstream states like Egypt and Sudan at odds with the interests of their upstream neighbors, such as Ethiopia. Ultimately, the likelihood of interstate conflict will only increase unless Nile River Basin countries

[246] "2012/2013 Season to be Impacted by Conflict, Fuel Prices, and Atypical Livestock Movements," *FEWS NET, USAID*, July 2012, http://www.fews.net/east-africa/sudan/food-security-outlook/july-2012.
[247] Stephan Faris, "The Real Roots of Darfur," *The Atlantic*, April 2007, https://www.theatlantic.com/magazine/archive/2007/04/the-real-roots-of-darfur/305701/.

are willing and able to find a way to share the increasingly limited resources of the Nile in a fair and sustainable manner.

Efforts at Cooperation on Nile Access

There have been various efforts at cooperation on Nile water access in the twentieth century and several past treaties influence the policies surrounding the use of the Nile's waters today. The first treaty, the Nile Water Agreement, was agreed to in 1929 by Egypt and Great Britain and granted Egypt the majority of the Nile waters. Under the treaty, Egypt was promised 48 billion cubic meters of water annually, while Sudan was allocated 4 billion cubic meters.[248] Egypt and Sudan would renegotiate this agreement in 1959 based on the annual flow at the Aswan Dam of 84 billion cubic meters, allocating "55.5 billion cubic meters (three-quarters) of the water to Egypt and 18.5 billion cubic meters (one-quarter) to Sudan," while the remaining 10 billion cubic meters would be assumed to be lost to evaporation on Lake Nasser.[249] Egypt still points to the favorable terms of these treaties to validate its large claims on the Nile's water resources, while the east African countries involved see them as a colonial relics to which they should no longer adhere.

Another agreement, the 1999 Nile Basin Initiative (NBI) included all relevant parties: Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, and Uganda with Eritrea as an observer. The NBI's mission at its signing was to be a forum that could "achieve sustainable socio-economic development through the equitable utilization of, and benefit from, the common Nile Basin water resources."[250] Many external actors, including the World Bank, support this initiative.

In April 2010, Ethiopia, Rwanda, Uganda, Kenya, and Tanzania signed the "Cooperative Framework Agreement" that promised to redistribute the Nile's water. Egypt, along with Sudan, argued that the deal was non-binding and boycotted the negotiations, but the remaining parties approved it after Burundi signed on in March 2011.[251] Egypt and Sudan still cite the 1929 and 1959 treaties as the legal basis for their current claims over the Nile's waters and their dispute of the legality of the 2010 Agreement.

A key aspect of the Cooperative Framework Agreement is the introduction of the term "water security," which is the riparian states' attempt to counter the "status of existing treaties" argument that Egypt and Sudan employ to protect their interests. However, the introduction of this concept, according to Professor Dereje Zeleke Mekonnen of Ethiopia's Addis Ababa University, is "non-legal, destructively elastic, and indeterminate," and represents an attempt to inject a "magic wand" that could lead to compromise between the states' incompatible positions and restart the stalled negotiations over rights to the Nile's water. While the text of Article 14 reads in part,

> Nile Basin states therefore agree, in a spirit of cooperation:
> (a) to work together to ensure that all States achieve and sustain water security
> (b) not to significantly affect the water security of any other Nile Basin State.[252]

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[248] David H. Shinn, "Nile Basin Relations: Egypt, Sudan and Ethiopia," July 2006, https://sites.google.com/site/davidhshinn/nile-basin-relations-1.
[249] Ibid.
[250] "One River One People One Vision," *Nile Basin Initiative*, 2018, http://www.nilebasin.org.
[251] "Minister: Egypt Will Not Sign Entebbe Agreement in Current Form," *Egypt Independent*, January 13, 2013, http://www.egyptindependent.com/news/minister-egypt-will-not-sign-entebbe-agreement-current-form.
[252] Ibid.

This non-binding language has caused major issues for Egypt and Sudan.

Cooperation to address diplomatic disagreements over the Nile's waters has also taken other forms besides international agreements and treaties. For example, an "International Panel of Experts," composed of six experts from Ethiopia, Egypt, and Sudan, and another four experts from outside the region, was assigned the job of investigating concerns over the GERD project. In 2013, the panel concluded that in planning the massive project Ethiopia had failed to take into account the likely environmental, hydrological, and socio-economic impacts the project would have on its downstream neighbors, in addition to ignoring the influence that climate change is projected to have on the Nile River system more generally.[253] While the panel's conclusions confirmed many of Egypt's concerns about the GERD, the Ethiopian government continued to contend that the dam would have a negligible impact on Sudan and Egypt and that water held in the GERD's reservoir would not be used for irrigation.

In 2015, the Egyptian, Ethiopian, and Sudanese heads of state met in Khartoum to sign a "Declaration of Principles" on the Grand Ethiopian Renaissance Dam. In this preliminary accord, meant to serve as a basis for future cooperation on the sharing of the Nile's waters, the parties committed to the principles of "fair and appropriate use," and refraining from "causing significant damage," among others.[254] Yet, while the agreement signaled a cooling of tensions between Egypt and Ethiopia, it did not deliver a resolution. Cairo has continued to express its reservations about the GERD and has consistently prodded diplomatic counterparts in the Ethiopian capital of Addis Ababa to take into account the findings of independent technical reports on the predicted downstream impacts of the dam.[255] Like construction of the dam itself, which is at least 62 percent completed,[256] the dispute over the life-sustaining waters of the Nile is far from being over.

[253] "GERD Panel of Experts Report: Big Questions Remain," *International Rivers*, March 31, 2014, https://www.internationalrivers.org/gerd-panel-of-experts-report-big-questions-remain.
[254] "Full Text of 'Declaration of Principles' Signed by Egypt, Sudan and Ethiopia," *Ahram Online*, March 23, 2015, http://english.ahram.org.eg/News/125941.aspx.
[255] Jacob Wirtschafter, "Here's Why Egypt's Nile River is in Danger," *USA Today*, September 29, 2017, https://www.usatoday.com/story/news/world/2017/09/29/egypt-nile-river-danger/679222001/.
[256] "Ethiopia's Grand Renaissance Dam 62 Pct Complete," *Xinhuanet*, October 21, 2017, http://www.xinhuanet.com/english/2017-10/21/c_136694651.htm.

Chapter 7: Central Asian Water Disputes

Introduction

Around the globe, transboundary water disputes are a major point of contention among riparian states. In Central Asia, two great rivers—the Syr Darya and the Amu Darya—empty into the Aral Sea. The Amu Darya originates in Afghanistan, forms the Afghan-Tajik border, and runs northwest to Turkmenistan before finally emptying into the Aral Sea in Uzbekistan. The Syr Darya is formed high in the mountains of Kyrgyzstan, flows through Tajikistan and Uzbekistan, and finally to Kazakhstan before emptying into the Aral Sea. Because of the number of countries involved and their competing interests over the seasonal needs from the rivers, no one state should dictate the water-sharing arrangements of the region.[257] A delicate balance then arises over water quotas and sharing mechanisms.

The Syr and Amu Darya rivers are crucial in several ways for those who depend on them. Some use the waters for irrigation of crops, while others use it for hydroelectric power generation or for drinking.[258] All, however, view its usage as a matter of utmost importance and a matter of national security. As in so many other places, climate change and resource mismanagement are threatening this delicate balance, which in turn, is threatening the region. Projections anticipate a flow reduction by 10-15 percent in the Amu Darya and 2-5 percent in the Syr Darya by 2050 as climate change continues melt the already shrinking glaciers of Central Asia.[259] As the amount and allocation of fresh water becomes increasingly uncertain and contested, rising tensions are possible as states vie with one another to protect their vital interests.

The two rivers empty in the Aral Sea, which was once the fourth largest lake in the world but has shrunk by more than 80 percent in the last half a century due to Soviet-era river diversions

[257] Thomas Bernauer and Tobias Siegfried, "Climate Change and International Water Conflict in Central Asia," *Journal of Peace Research* 49, no. 1. (2012): 227-239.
[258] Ibid.
[259] Jakob Granit et al., *Regional Water Intelligence Report Central Asia: Baseline Report*, Regional Water Intelligence Report No. 15, (Sweden: United Nations Development Programme, 2010).

for irrigation.[260] The lake's economic importance as well as its use for basic needs of the surrounding population make what is typically coined "The Aral Sea Crisis" one of the most well-documented and publicized changes to an area of ecological value. The expected flow reductions in the rivers that feed the lake coupled with the expected surface evaporation from progressively higher average temperatures continue to threaten the very existence of what remains of the Aral Sea. The ability for climate change to negatively influence the continuing crisis has the potential to exacerbate existing tensions between riparian neighbors.

History of the Region and Resources

Syr Darya

Prior to the breakup of the Soviet Union in 1991, the Syr Darya was an intrastate river system. It was entirely within the authority of the USSR and Moscow, which set water quotas for each of the riparian republics.[261] Built in 1974, the Toktogul Dam and Reservoir in Kyrgyzstan allows for the controlled release of the Syr Darya's flow for strategic purposes. The downstream republics of Kazakhstan and Uzbekistan were the main recipients of water deliveries along the river and used their allotments primarily for irrigation purposes. In the era of Soviet rule, Moscow would instruct Kyrgyzstan to release water to Uzbekistan and Kazakhstan during the spring to fall months in order to irrigate the crops downstream, as the two latter states were major producers of wheat and cotton. In turn, hydrocarbon-rich Uzbekistan and Kazakhstan would provide Kyrgyzstan with cheap coal, gas, and oil during their cold winter months. Rather than keeping the electricity for itself, the energy produced by the Toktogul Dam in Kyrgyzstan was evenly distributed amongst the Central Asian republics.[262]

With the fall of the Soviet Union, the Syr Darya's water changed from a shared resource to a disputed, limited commodity. After 1991, energy shipments from downstream states to Kyrgyzstan declined dramatically. As a result, costs for operating Kyrgyz power plants, which had run on discounted or free fossil fuels from neighboring republics, skyrocketed.[263] In response to this, production from these power plants greatly diminished as costs had grown too high. To make up for the lost power, Kyrgyzstan turned the Toktogul Dam from mainly an irrigation regulation venture into a power producing venture. With this switch, hydropower grew to comprise about 90 percent of Kyrgyz power needs.[264] This in turn created conflict with downstream states.

Compounding this tension is the fact that the water needs of the upstream states (primarily Kyrgyzstan) and the needs of the downstream states, Kazakhstan, and Uzbekistan, are diametrically opposed. Both Uzbekistan and Kazakhstan use the Syr Darya primarily for the irrigation of crops. Their main demand for water begins in the spring and ends in the fall. They therefore advocate for the Toktogul Reservoir to release most of the Syr Darya's annual flow

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[260] Sandra Postel, "What the Disappearing Aral Sea Tells Us About the Value of Water," *National Geographic Blogs*, October 14, 2014, https://blog.nationalgeographic.org/2014/10/14/what-the-disappearing-aral-sea-tells-us-about-the-value-of-water/.

[261] Jenniver Sehring and Alfred Diebold, "Water Usage and Water Management in the Soviet Union," in *From the Glaciers to the Aral Sea: Water Unites* (Trescher Verlag, 2012), http://www.waterunites-ca.org/themes/8-water-usage-and-water-management-in-the-soviet-union.html.

[262] Ibid.

[263] Bernauer, "Climate Change and International Water Conflict in Central Asia."

[264] Ibid.

during these warm summer months.[265] Conversely, Kyrgyzstan uses the Syr Darya's water primarily for power production. Kyrgyzstan's power demands are highest in the winter when temperatures are coldest. The country thus prefers proportionate release of water from the Toktogul Reservoir to occur during the cold winter months.[266]

In an attempt to bridge this gap, Kazakhstan, Uzbekistan, and Kyrgyzstan signed an agreement on quantitative goals for monthly releases from the Toktogul Reservoir in 1998, and Tajikistan joined one year later. The agreement also stated that Kyrgyzstan would supply the two downstream states with 2,200 million kilowatt hours (kWh) of electricity (1,100 kWh each).[267] In turn, Kazakhstan and Uzbekistan would supply Kyrgyzstan with fixed amounts of gas, electricity, coal, and oil during the winter months. These amounts would be specified each year through negotiations.[268]

The newly independent states tried to emulate the Soviet era system, but their plan was met with challenges. One major flaw in this plan became apparent when the prices of hydroelectric power and fossil fuels diverged. This made it impossible for Kyrgyzstan to turn its additional water releases into income. Yet the agreement was implemented until an unusual decrease in precipitation in 2008.[269] This anomaly, coinciding with an El Nino event, strained the Toktogul's ability to meet the region's water needs. After this year, summer releases remained low in favor of winter releases, which suited Kyrgyzstan's power needs, but not the its riparian neighbors' water needs.

Amu Darya

Much of the Amu Darya's course runs through the former USSR, and many of the disputes connected to its use in Central Asia are markedly similar to those relating to the use of the Syr Darya. Akin to Kyrgyzstan's use of the Syr Darya, the upstream republic of Tajikistan uses relatively low quantities of the Amu Darya water for irrigation, and the high velocity of the river in the republic lends itself to hydroelectric production.[270] Conversely, the downstream republics of Turkmenistan and Uzbekistan use the Amu Darya's resources primarily for irrigative purposes.[271] Moscow facilitated a similar system of reciprocity with upstream water being released in summer months to irrigate crops downstream, and in turn hydrocarbons being sent by downstream states to their upstream neighbors in the winter.

However, growing demand for water for drinking, irrigative, and hydroelectric purposes eventually put a strain on the river basin's resources. Moscow responded by creating the River Basin Organization (BVO) in 1987 to regulate water limits in the Soviet Republics.[272] Since the fall of the USSR, these water quotas have stayed in place. However, each of its former republics, now independent states, has created programs that clash with their water quotas. Both

[265] Ibid.
[266] Ibid.
[267] Ibid.
[268] Ibid.
[269] Ibid.
[270] Shira Babow, "The Water-Energy Nexus in the Amu Darya River Basin: The Need for Sustainable Solutions to a Regional Problem," *Global Energy Network Institute*, 2012.
[271] Ibid.
[272] Ibid.

Turkmenistan and Uzbekistan have increased their agricultural production, necessitating more water. Compounding this issue further, Uzbekistan and Turkmenistan have invested heavily in cultivating cotton, a notoriously thirsty plant. Tajikistan has expanded its hydroelectric output to meet demand, further diminishing the level of water in the Syr Darya.[273] Additionally, northern Afghanistan has expanded its cropland, further drawing resources from the river.[274] As such, the Syr Darya's flow has decreased significantly over the last decade.

Threats to Water Reservoirs and the Ecosystem in the Aral Sea

The substantial increases in water withdrawals from both the Syr and Amu Darya have had transformative impacts on the region's ecosystem. Both rivers flow into the Aral Sea, bordered by Uzbekistan and Kazakhstan. Despite its name, the Aral Sea is actually a terminal lake whose drying up has been well documented and much feared. Historically, a general equilibrium has been reached between net evaporation of surface waters, ground water inflow, and river discharge into the lake. In fact, the Aral Sea used to be the fourth largest lake in the world, but it now contains only 10 percent of that water volume.[275] As river runoff decreases and the waters salinize—both trends that are expected to continue with climate change in the long run—the delicate ecological equilibrium of the Aral Sea is thrown into chaos.

Irrigation practices initiated under the Soviet Union have greatly affected the Aral Sea. Drawing heavily from both the Syr and Amu Darya Rivers, the main sources of inflow for the Aral Sea, irrigation programs have diminished the amount of water reaching the Aral Sea. In fact, water withdrawals were so extensive from 1974-1976 that the Syr Darya reportedly provided no flow to the Aral Sea in those years. Additionally, the Amu Darya only provided a very minimal flow to the Aral Sea in 1982-1983, 1985-1986, as well as in 1989.[276] As a result of these cutbacks in inflow, the Aral Sea split into two bodies from 1987-1989—the North (or Small) Aral Sea and the South (Large) Aral Sea. Despite increased precipitation coupled with cutbacks in irrigation withdrawals (12 percent between 1980 and 1995), the Aral Sea continues to shrink, leaving behind massive and arid salt flats.[277]

The desiccation of the Aral Sea has had notable ecological impacts: between 1960 and 2010, its surface area has decreased from 68,000 km^2 to 14,280 km^2 and its total water volume declined from 1,093.0 km^3 to 98.1 km^3.[278] The Aral Sea's salinity has also drastically increased from 10ppt in 1960 to 92ppt in 2004.[279] Due to these changes, the Aral Sea's populations of freshwater fish suffered greatly and, over the course of twenty years between 1960 and 1980, commercial fishing catches fell from 43,430 tons to zero.[280] Coastline recession has decreased shallow spawning and eliminated feeding ground for many types of fish, while increased salinity

[273] Ibid.
[274] Ibid.
[275] Angela Fritz, "The Aral Sea Was Once the Fourth Largest Lake in the World. Watch it Dry Up," *The Washington Post*, September 30, 2014, https://www.washingtonpost.com/news/capital-weather-gang/wp/2014/09/30/the-aral-sea-was-once-the-fourth-largest-lake-in-the-world-watch-it-dry-up/?utm_term=.d7c1adf3c825.
[276] Ibid.
[277] Ibid.
[278] Behzod Gaybullaev et al. "Changes in water volume of the Aral Sea after 1960," *Applied Water Science.* 2012, *2*, 285–291.
[279] "The Aral Sea Crisis," *Columbia University,* 2008, http://www.columbia.edu/~tmt2120/environmental%20impacts.htm.
[280] Ibid.

levels due to decreasing freshwater influx, increasing amounts of agricultural wastewater, and increased rates of evaporation have threatened organisms' habitats.[281] For certain species, some of these ecological threats have irreversibly impacted them; the Aral Salmon (*Salmo trutta aralensis*) has subsequently gone extinct.[282] In contrast, introduced species such as the Black Sea Flounder have been flourishing in the North Aral Sea and stabilization projects have decreased its salinity, in the hopes of bringing back its indigenous pike and carp populations.[283]

Not only have faunae populations declined in the Aral Sea itself, but they have also declined in the river deltas. Before 1960, more than 70 different types of mammals lived in the Syr and Amu Darya deltas, but today only 32 remain.[284] This decline occurred concurrently with the loss of bird species in the deltas; before 1960, 319 different species of birds populated the area and now only 160 remain.[285] Similar falloffs have been recorded in Tugay vegetation habitats. Tugay forests are riparian ecosystems subject to and sustained by intermittent flooding and groundwater. Salt pans have emerged, inhibiting the growth of vegetation which otherwise provides habitats for a wide variety of animals including twenty varieties of amphibians, over 300 types of birds and upwards of sixty species of mammals.[286] Yet due to habitat destruction, these populations are at risk.

The effects of desertification have not only impacted plant and wildlife habitats along the Amu Darya and Syr Darya river deltas and the Aral Sea; they have had an immense impact on human populations as well. The local fishing industry has collapsed. This has occurred mostly in the South Aral Sea where salinity levels remain extremely high.[287] As a result, aquatic life is a rarity. However, there is promise in the North Aral Sea. Its slightly lower salinity means fish such as flounder, carp, and perch are relatively abundant. Still, tens of thousands of people have lost their jobs as the overall fish populations have declined. Furthermore, animal husbandry has been threatened not only in the desert adjacent to the Aral Sea but in the river deltas as well.

The dried-up portions of the Aral Sea that produce tremendous quantities of sand, salt, and dust further affect human populations. Whipped up by winds, these particulates can form massive salt and dust plumes. Imaging beginning the 1970s has shown these plumes extending nearly 500km downwind of the Aral Sea, depositing dust and salt over an enormous area.[288] Salts blown overland by wind settle on vegetation and have detrimental effects such as reducing crop yields or killing the plants outright.[289] Not only do these deposited particulates endanger vegetation, they also threaten animals directly by contaminating their food supply. Increased levels of respiratory

[281] Philip Micklin, "The Aral Sea Disaster," *Annual Review of Earth and Planetary Science* 35 (2007): 47-26.
[282] Ibid.
[283] Ibid.
[284] Ibid.
[285] Ibid.
[286] Ibid.
[287] Karen Bennett, "Disappearance of the Aral Sea," *World Resources Institute,* accessed March 01, 2018, http://www.wri.org/blog/2008/05/disappearance-aral-sea.
[288] Ibid.
[289] Shira Babow, "The Water-Energy Nexus in the Amu Darya River Basin: The Need for Sustainable Solutions to a Regional Problem," *Global Energy Network Institute*, 2012, http://www.geni.org/globalenergy/research/water-energy-nexus-amudarya-river/Water-Energy%20Nexus-AmuDarya-River-RD.pdf.

illness, eye problems, as well as throat and esophageal cancers have been attributed to airborne salt and dust plumes, which are also laden with toxic chemicals from formerly used pesticides.[290]

While the supply of water to the Aral Sea is declining, the supply of water to the Syr Darya is not, at least for the short term. Glacial melt in the mountains will continue to feed the headwaters of the river with an adequate supply, but as glaciers retreat, they can reveal geologic irregularities in the underlying basin rock.[291] Substantial amounts of meltwater can be trapped in these irregularities, which can be vulnerable to sudden collapse and cause singular massive flooding for downstream communities--particularly in the Fergana Valley in the case of the Syr Darya. Another potential issue for downstream communities relating to runoff is a changing timetable for freshwater availability—climate change is shifting the seasonality of the peak runoff to earlier in the year. The peak runoff is being shifted from a spring/early summer schedule, to a late winter/early spring schedule, meaning less water is available later when over 90 percent of the water used for irrigation is needed.[292] Changing riparian variables such as these can have marked impacts on populations that rely on the regularity of seasonally changing water resources.

Efforts to Save the Aral Sea

In response to the crisis, all five states sharing the Aral Sea Basin—Kazakstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan—came together and developed a strategy to address the desertification of the Aral Sea in the early 1990s. Around the same time, the World Bank and agencies of the United Nations developed an Aral Sea Program to assist Aral Sea Basin countries in their efforts. In 1993, the International Fund for Saving the Aral Sea (IFAS) was established. According to the European Business Review, "The main objectives of IFAS are to finance programs to save the sea, and to bring about the ecological rehabilitation of the region and the Aral Sea Basin as a whole taking into account the interests of all."[293] The overall vision of the organization is, according to the IFAS itself, "improved living conditions for the people of Central Asia."[294] In 2003, with the cooperation of the World Bank, work on the first phase of the North Aral restoration project began. This includes the eight-mile Kok-Aral dam, completed in 2005, which allows water from the Syr Darya to accumulate in the Northern Aral Sea instead of over-draining down slope into the Southern Aral Sea--aiding in wetland-ecosystem restorations in the northern body.[295]

As of 2016, efforts to restore the North Aral Sea had made substantial gains. Water levels have increased by 4 meters, the lake's surface area has increased by 20 percent, and salinity levels have nearly returned to 1960 levels. This has had an impact on the regional fishing economy, as fish catches have increased from 52 tons to 11 thousand tons from 2004 to 2015. Life around the northern Aral Sea is slowly reviving but more work is clearly needed. Full recovery of the North

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[290] Journal of Rural and Remote Environmental Health 1(2): 29-34 (2002). The Aral Sea environmental health crisis. Phillip Whish-Wilson. Introduction.
[291] Thomas Bernauer and Tobias Siegfried, "Climate Change and International Water Conflict in Central Asia," *Journal of Peace Research*, 2012
[292] Ibid.
[293] Martin Banks, "More Effort Needed to Save Aral Sea from 'Environmental Disaster,'" *European Business Review*, October 20, 2016, http://www.europeanbusinessreview.eu/page.asp?pid=1621.
[294] "Who We Are," *International Fund for saving the Aral Sea*, 2011, http://ec-ifas.waterunites-ca.org/about/index.html.
[295] Banks, "More Effort Needed."

Aral Sea requires further modernization of the irrigation system and continued support from the countries affected as well as the international community.[296]

The second phase of the project is to restore the South Aral Sea, but there has been little progress made so far. As recovery efforts prove at least temporarily effective in the North Sea, they occur at the detriment of the South Sea where fresh water would typically flow. As a result, the eastern lobe of the South Aral Sea completely dried up in 2014 for the first time in 600 years.[297] While Kazakhstan has introduced drip irrigation and other water-saving technologies for agriculture, Uzbekistan and Turkmenistan have yet to make any significant steps in this direction. To the contrary, Uzbekistan and Turkmenistan have actually increased the volume of water-intensive cotton crops on nearby farmland. Additionally, according to the *European Business Review*, "Kyrgyzstan has frozen its participation in the activities of International Fund for Saving the Aral Sea, whilst Tajikistan and Turkmenistan have distanced themselves from the problems of the region."[298] Without a collective agreement among the Aral Basin states and international financial assistance, it is highly unlikely that the Southern Aral Sea will be revitalized.[299]

Policy Implications

The Aral Sea can recover to some extent if it begins to return to a state of natural equilibrium. Therefore, many policy recommendations for the Aral Sea call for water sharing agreements among the riparian states in the region. There are still efforts underway to construct dikes and dams within the remaining parts of the Aral Sea to mitigate the effects of excessive withdrawals from the rivers that feed it.

One possibility is to update the 1998 Agreement regarding water sharing along the Syr Darya. The 1998 Agreement was derailed by a drought in 2008, which was precipitated by an El Niño event. Rather than having quotas set up on a yearly basis, this agreement should be more far-sighted. A multi-year perspective in water reserves is needed in order to compensate for abnormally dry years, as well as abnormally wet ones.[300] Such an outlook will plan for variations in glacial melt, as well as timing differences with regards to resource needs between the upstream and downstream states.

Furthermore, explicit language in the 1998 Agreement is necessary to address the need for upstream states to be monetarily compensated for water storage.[301] The Uzbek notion that downstream states are entitled to free water access is not internationally accepted. Of the 145 treaties signed in the twentieth century on water use in transboundary rivers, nearly half of them address water allocation issues.[302] Not only do these treaties outline payments for water deliveries, but they also provide precedent for reverse payment if water is withheld. Economic analysis shows

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[296] Ibid.
[297] Brian Clark Howard, "Aral Seas Eastern Basin Is Dry for First Time in 600 Years," *National Geographic*, October 2, 2014, https://news.nationalgeographic.com/news/2014/10/141001-aral-sea-shrinking-drought-water-environment/.
[298] Banks, "More Effort Needed."
[299] Ibid.
[300] "Water Energy Nexus in Central Asia: Improving Regional Cooperation in the Syr Darya Basin," *The World Bank*, 2004.
[301] Ibid.
[302] Erik Ansink and Arjan Ruijs. "Climate Change and the Stability of Water Allocation Agreements." *Environmental and Resource Economics* 41, no. 2 (2008): 249-66.

that, when the Toktogul Reservoir is switched from a power regime to an irrigation regime, the costs increase 3.6 times but benefits increase 4.6 times.[303] Therefore, it is more beneficial overall for the region to use the water for irrigation purposes. However, in this case, the costs fall upon Kyrgyzstan while the benefits accrue to Uzbekistan and Kazakhstan. This therefore necessitates a payment for water services to Kyrgyzstan.

Additionally, the 1998 Agreement needs to enumerate a mechanism for dispute resolution.[304] This may take the form of legal measures at the International Court of Justice, the Permanent Court of Arbitration, or another conflict resolution method. Lastly, the energy trade must be decoupled from the water trade. Both should be valued at market prices so that they can be traded without any distortion.

If states divested from practices that are freshwater intensive, the tension between them over shared river resources could be alleviated to a great extent. For Kyrgyzstan, this could mean investing in solar and wind energy. This would not only reduce the country's reliance on Uzbek and Kazakh fossil fuel shipments, but would also decrease their dependence on the Syr Darya for hydroelectric power. A similar policy suggestion could be made for Tajikistan. Further, Uzbekistan, Kazakhstan, and Turkmenistan could all invest in less water-intensive farming practices by switching to cultivation plants other than cotton or investing in water recycling infrastructure. Although these policy suggestions may be costly for these states in the short term, preserving the natural resources of the region is a necessity for them in the long run.

[303] "Water Energy Nexus in Central Asia," *The World Bank*.
[304] Ibid.

Part II: The Threat of Sea Level Rise

Introduction

Rising sea levels are one of the primary and most dangerous consequences of climate change. Throughout the world, rising seas will endanger physical infrastructure (including arable land), ecosystems, and the lives and livelihoods of a vast number of people, with significant economic and security ramifications. The time to fully prevent the phenomenon has passed; the consequences of historic human emission of CO_2 on sea level have yet to be fully realized, and will have to be dealt with. In numerous countries, many centers of economic and political life are located in coastal areas highly vulnerable to a rise in sea levels. Substantial investments in infrastructure will be needed to keep the most catastrophic consequences of rising seas at bay. In a policy environment characterized by budgetary deficits and rising national debt, such as in the United States, making such investments will prove challenging from both an economic and a political perspective.

This section explores several disparate regions threatened by rising seas as a consequence of climate change. While this section is centered on the United States, it demonstrates the global implications of rising oceans. Countries like the Netherlands have already been grappling with such challenges for decades and have made large investments to adapt to rising sea levels in the form of massive infrastructure projects such as Delta Works. China is also particularly susceptible to rising sea levels, with up to 100 million people living in coastal areas.

In developing countries, the consequences of rising sea levels could be even more disastrous. Without increases in international aid, these states lack the resources to address such issues on their own. As coastal flooding becomes more prevalent, it is likely to cause large-scale migrations. Bangladesh and Egypt, both extensively discussed in this monograph, illustrate the challenges faced by developing states.

In many Southeast Asian states, such as Indonesia and Malaysia, a similar rise in sea levels would endanger several population centers and areas of economic significance, particularly in agricultural regions. Migration originating in developing countries will have consequences well beyond such states. This will be a contributing factor in the rise of nationalism and border protection around the world. The popular backlash to the wave of migration from conflict zones in the Middle East, which has overwhelmed states in Europe, is an early example of such trends

directly tied to climate change. In low-lying island states, rising sea levels will not only devastate the tourism upon which these countries heavily rely, but could also ultimately lead to complete immersion and disappearance. Besides the inherent catastrophe this will represent for the inhabitants of these island states, the disappearance of entire countries poses new legal challenges. While land has traditionally been viewed as necessary for the legal recognition of a state, changes in legal definitions and institutions might be necessary to accommodate the displaced people of low-lying island states.

Rising sea levels will also have direct security implications. Coastal military infrastructure is likely to be affected by rising sea levels. This section examines Hampton Roads, an area of Virginia crucial for U.S. Navy operations, which is particularly vulnerable to rising sea levels. It also discusses Diego Garcia Island, an outpost in the Indian Ocean key to both America's and the North Atlantic Treaty Organization's (NATO) capacity to project its military power in eastern Africa and South and Southeast Asia. Defense installations in both areas will suffer from even the smallest rises in sea levels. Significant investment by the Department of Defense will be needed to keep such installations fully operational. American defense readiness and capabilities are likely to suffer due to rising sea levels and other consequences of climate change.

Chapter 8: Low-Lying Countries

A small yet significant fraction of the global population lives on tiny outcroppings in the middle of vast ocean expanses. Small Island Developing States (SIDS) are scattered all over the globe but appear mostly in the Caribbean Sea, Indian Ocean, and Pacific Ocean. Many of these states are low-lying and particularly vulnerable to the deleterious effects of climate change. As the seas begin to rise, the circumstances of these island states will become perilous. At the 2017 United Nations General Assembly, Tuilaepa Sailele Malielegaoi, the Prime Minister of Samoa, frankly stated that "As small island Pacific countries, we are no longer protected by our isolation." In additional to these island nations, perilously low-lying continental nations are facing a similar crisis.

Over the past century, mean sea levels around the globe have increased by roughly 10 to 20 centimeters (four to eight inches).[305] In the past 20 years, the rate of increase has been twice that of the preceding 80 years, indicating that future sea level rise won't necessarily proceed linearly.[306] Data from the IPCC indicates that the oceans may rise between 0.3 and 1 meter (one and three feet) by 2100.[307] Many reports have been issued on the danger of sea level rise to populous coastal cities such as New York, London, or Miami, yet the fundamental habitability of these cities is not immediately threatened. For many SIDS, however, sea level rise poses a stark existential threat. Many SIDS are atolls or reefs that barely break the surface of the waves. The Marshall Islands, one of many such small islands facing submersion, has an average elevation of 2 meters (6.6 feet) above sea level.[308] Rising sea levels threaten many SIDS with disappearance as rising waters inundate ever-greater chunks of land. This creates both humanitarian and legal dilemmas. Will these drowned countries still be considered states? And where will the hundreds of thousands of displaced and potentially stateless people be relocated? The problem of sea level rise is highly time-sensitive, as the ever-accelerating pace of warming intensifies the challenges

[305] "Sea Level Rise," *National Geographic*, http://ocean.nationalgeographic.com/ocean/critical-issues-sea-level-rise/.
[306] Ibid.
[307] Ibid.
[308] U.S. Central Intelligence Agency, *The World Factbook: Maldives*, July 22, 2015, https://www.cia.gov/library/publications/the-world-factbook/geos/mv.html.

SIDS face. For low-lying mainland countries like Bangladesh, storm surge is the most destructive consequence of climate change thus far. Although nations like Bangladesh will not necessarily be completely eclipsed by the ocean in the near future like SIDS, they do face the extreme storm surges that are able to sweep across their unvarying topography.

Reasons for Sea Level Rise

As humans continue to introduce carbon dioxide and other "greenhouse gases" (GHGs) into the atmosphere from the burning of fossil fuels, the Earth's infrared radiation is trapped in greater concentrations closer to the surface. This effect heats up the troposphere—the lowest layer of Earth's atmosphere—and the world's oceans. Higher temperatures melt polar ice and introduce substantial amounts of freshwater to the world's seas. Presently, about 10 percent of the Earth's land area is covered with glacial ice.[309] This melting potential is particularly worrisome because many polar regions hover near 0°C in the summer, and even slight warming can induce melting. Since 1951, the Arctic has warmed at a rate nearly twice the global average.[310] Additionally, oceans have the capacity to absorb much of this heat, which contributes to sea level rise in the form of thermal expansion.[311]

Kiribati, an archipelago nation of 100,000 people in the Pacific, is experiencing increasing sea levels, coastal erosion, wave height and frequency, and more frequent storm surges.[312] This has put more pressure on both its shore areas and seawalls and lead to a variety of problems including inland flooding and accelerated erosion. These phenomena are typical for SIDS.

Physical Effects of Sea Level Rise

Changes in the oceans are having a significant impact on low-lying islands globally. The most obvious threat is inundation. Many low-lying islands are ring shaped coral formations, known as atolls, which peak just above the ocean's surface. Atolls generally have very little elevation variation, and lie flat on the water. The Maldives, for example, is located in the middle of the Indian Ocean and is the flattest country on Earth.[313] The highest point in the country is around 2.4 meters (eight feet) above sea level, but over 80 percent of the land in the Maldives lies below one meter (3.3 feet) above sea level. A slight rise in sea level threatens the whole country. In fact, a one-half meter (1.5-foot) rise in sea level, projected to occur well before 2100, would deprive the Maldives of 77 percent of its territory.[314] Many other SIDS face similar threats. Residents in the Marshall Islands have been forced to clamber on the roofs of buildings to escape the waves from more frequent storm surges.[315] These storm surges bring salt water inland, which wreaks havoc on the ecology of these low-lying island states and contaminates groundwater resources. This threatens agriculture and the supply of drinking water, particularly in the dry season.

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[309] "Facts About Glaciers," *National Snow and Ice Data Center*, 2018 https://nsidc.org/cryosphere/glaciers/quickfacts.html.
[310] "The Melting North," *The Economist*, June 16, 2012, http://www.economist.com/node/21556798.
[311] Sea Level Rise," *National Geographic.*
[312] Republic of Kiribati, "Coastal Erosion," *Kiribati Climate Change*, accessed March 29, 2018, http://www.climate.gov.ki/category/effects/coastal-erosion/.
[313] "Climate Hot Map: Republic of Maldives," *Union of Concerned Scientists*, 2011, http://www.climatehotmap.org/global-warming-locations/republic-of-maldives.html.
[314] Ibid.
[315] John David Sutter, "You're Making This Island Disappear," *CNN*, June 2015, http://www.cnn.com/interactive/2015/06/opinions/sutter-two-degrees-marshall-islands/.

Economic Effects of Sea Level Rise

Rising sea levels also pose great economic risks, but a dramatic rise in sea level is not necessary to threaten a country's economic vitality. For example, housing and major infrastructure on the Maldives archipelago are concentrated along the coastline.[316] The country's two international airports lie within 50 meters of the shoreline, which means that the Maldives' tourism sector—which contributes nearly 30 percent of the island's gross domestic product (GDP) and over 60 percent of its foreign exchange receipts[317]—will be directly threatened once water rises past the shore and encroaches on the runway. The pristine beaches that attract foreign tourists will be the first things to vanish as waters rise.

Rising sea levels may also affect states' security and strategic capabilities. Diego Garcia is the largest island in the Chagos Archipelago, a British-controlled chain of islands that sits in the Indian Ocean about 3,500 km east of Tanzania. Due to its location, it serves as a forward operating hub for areas on the Indian Ocean littoral and provides key access to the Middle East and heavily transited Eurasian shipping routes. Diego Garcia hosts a strategically important U.S. military base that allows the American military to react quickly in the Indian Ocean basin. Diego Garcia has been referred to as a "dream base" because it does not have a local population and its location ensures its physical security.

Yet climate change poses a threat to this "unsinkable aircraft carrier." Diego Garcia—similar to the Maldives, Marshall Islands, and Kiribati—is a coral atoll with an average elevation of approximately 0.9 meters (three feet) above sea level,[318] and thus sea level rise poses an existential threat to the island. While the United States may build seawalls to protect against ocean surges, the future viability of this "critical logistics hub for U.S. and British forces in the Middle East"[319] is threatened by land degradation and continually rising sea.

Legal Implications of Sea Level Rise

In 2014, Kiribati purchased roughly 21 square kilometers (eight square miles) of land in Fiji to relocate its entire population should the island chain be subsumed by the waves. Should such an unprecedented population transfer occur, would Kiribati remain a recognized state? Customary international law dictates that statehood requires territory to govern, a permanent population, and a government.[320] These three requirements were codified in the 1933 Montevideo Convention. If the requirement of a territory to govern precludes disappeared islands from being considered states, what happens to the citizens of these states? Article 1 of the Convention Related to the Status of Stateless Person (1954) defines a stateless person as, "a person who is not considered a national by any State under the operation of its law."[321] If maintaining a territory is a necessity of statehood and this is lost, then former residents of island states may not be considered nationals by any existing state, rendering them stateless refugees. However, it must be noted that

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[316] "Climate Hot Map: Republic of Maldives," *Union of Concerned Scientists*.
[317] U.S. Central Intelligence Agency, *The World Factbook: Maldives*.
[318] Andrew S. Erickson, Ladwig C. Walter III, and Justin D. Mikolay, "Diego Garcia and the United States' Emerging Indian Ocean Strategy," *Asian Security* 6, no. 3, 2010.
[319] Foley, "Military Basing and Climate Change."
[320] Susin Park, "Climate Change and the Risk of Statelessness: The Situation of Low-lying Island States" *United Nations High Commissioner for Refugees*, 2011, http://www.unhcr.org/en-us/protection/globalconsult/4df9cb0c9/20-climate-change-risk-statelessness-situation-low-lying-island-states.html.
[321] Ibid.

this is a general requirement for becoming a state, not necessarily a rule for remaining a state. Nonetheless, it is clear that the total inundation of some SIDS will pose an unprecedented legal conundrum.

Policy Options

Although they face the brunt of rising sea levels, small island states hardly contribute to climate change. In total, the island states of the Pacific Ocean emit .03 percent of the world's greenhouse gases.[322] While reducing carbon emissions into the future is certainly easier said than done, low-lying islands will still have to contend with the carbon already in the atmosphere. Research indicates that "the mean lifetime of the [atmospheric carbon dioxide] attributable to anthropogenic emissions is around 30,000 to 35,000 years" before ocean uptake and geological processes reabsorb it.[323] Because of the vast quantities of GHGs already emitted, the challenge facing many SIDS is not how to avoid climate change, but how to adapt to its effects.

Unfortunately, most SIDS do not have the resources to invest in robust sea walls to stave off rising waters, meaning that they will, for the most part, have to turn to other strategies. Despite their calls to action addressing the international community or their admonishment of some high-GHG-emitting countries, representatives of low-lying countries will have to deal with the lagging consequences existing GHG concentrations. One tactic is relocation, as exemplified by Kiribati's land purchase from Fiji, or in the significant community of over 10,000 Marshallese now settled in Springdale, Arkansas.[324] However, no one policy is likely to reverse sea level rise, and as such the inundation of low-lying islands is likely inevitable. In many cases of SIDS threatened by climate change, humanitarian support for displaced persons is likely to be the most plausible means of adaptation.

Flooding and Storm Surge in Bangladesh

Storm surges occur when abnormal water levels quickly rise due to the atmospheric pressure shifts and wind that accompany storms. Similar to tidal waves or tsunamis, storm surges inundate large portions of coastal areas, and, as sea levels continue to rise, these surges have the potential to cause more devastation than the storm itself. Bangladesh, located in South Asia, is especially vulnerable to storm surges. Here, more than almost anywhere else in the world, they have the ability to cause widespread destruction due to a confluence of environmental and geographical factors that make storm surges in Bangladesh especially severe.

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[322] Sutter, "You're Making This Island Disappear."

[323] Zeke Hausfather, "Common Climate Misconceptions: Atmospheric Carbon Dioxide", *Yale Climate Connections*, 2018, https://www.yaleclimateconnections.org/2010/12/common-climate-misconceptions-atmospheric-carbon-dioxide/.

[324] For some context, from 1946 to 1958 the U.S. performed 67 thermonuclear weapon tests on or near the Marshall Islands. As a result, in 1986, the U.S. agreed to the "Compact of Free Association, which stipulated that Marshallese citizens can emigrate freely to the United States and stay indefinitely without visas. Springdale, Arkansas became the epicenter of the Marshallese "diaspora" after an Island resident named John Moody moved to the area in the 1980s to work for Tyson foods. Word quickly spread back to the Marshall Islands that Springdale was rich with jobs and so began steady chain migration to the area. Today the migration is less about jobs and more about the survival of the Marshallese people in the face of climate change. For more information, see: Mark Abadi, "Thousands of 'Climate Refugees' Could be Soon Heading to this Middle America Town," *Business Insider*, February 5, 2016, http://www.businessinsider.com/marshallese-climate-refugees-head-to-arkansas-2016-2.

On November 15, 2007, Cyclone Sidr made landfall in Bangladesh. The cyclone and its accompanying storm surge led to the deaths of over 3,400 people, according to the United Nations. Over 9 million people were affected by the storm and 563,967 homes were destroyed, with another 913,447 damaged.[325] Furthermore, flooding destroyed 750,000 acres of cropland[326] and disrupted the incomes of 567,000 Bangladeshis.[327]

Storm surges threaten the lives and livelihoods of Bangladeshis by polluting freshwater sources used for public consumption and crop irrigation. Soil erosion, waterlogging, and oversaturation of the soil are also very common results of storm surges.[328] Threats to agriculture as well as aquaculture put enormous pressure on Bangladesh's capacity to feed itself, which in turn may force migrations (primarily to India).[329] India has recently taken measures to prevent immigration from its eastern neighbor.

Since 2012, the Indian government has constructed fencing to block off at least 90 percent of its 4,096-km border with Bangladesh.[330] As Sanjeev Tripathi, an analyst with Carnegie India told *CNN*, India took this step because years of illegal immigration from Bangladesh have had "serious implications for [India's] resources and national security."[331] Complete with floodlights, armed patrols, and barbed wire, this fence is designed to keep migrating Bangladeshis out of eastern India—although some contend that it is less than effective.[332] Previous instances of violence between India's Border Security Forces and illegal migrants has exacerbated cross border tensions, and the fencing has is regarded poorly by Bangladeshis.[333] Should storm surges compel mass migrations, more pressure will be put on this already tenuous relationship.

Why is Bangladesh Susceptible?

Bangladesh's geographical location makes the country highly vulnerable to storm surges. According to some scientists, the single most important geographical factor is the phenomenon of re-curvature.[334] Tropical cyclones generally travel on an east-to-west track as per the general circulation of the atmosphere at those latitudes. However, within the Bay of Bengal, cyclones recurve, or turn from a westerly heading and move north or even northeast.[335] If this phenomenon did not occur, most cyclones would make landfall between Somalia and Saudi Arabia. Instead,

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[325] "Super Cyclone Sidr 2007: Impacts and Strategies for Interventions," *Government of the People's Republic of Bangladesh Ministry of Food and Disaster Management*, February 2008, https://www.preventionweb.net/files/9470_cyclonebangladesh.pdf.
[326] Moazzem Hossain, "Climatic Hazards and the Bay of Bengal Delta," *South Asia Journal* 2 (October 2011): http://southasiajournal.net/climatic-hazards-and-the-bay-of-bengal-delta-moazzem-hossain/.
[327] "Super Cyclone Sidr 2007," *Government of the People's Republic of Bangladesh Ministry of Food and Disaster Management*.
[328] Hossain, "Climatic Hazards."
[329] Ibid.
[330] Huizhong Wu, "India Wants to Seal its Borders with Pakistan and Bangladesh", *CNN*, March 29, 2017, https://www.cnn.com/2017/03/28/asia/india-pakistan-bangladesh-borders/index.html.
[331] Ibid.
[332] Sudha Ramachandran, "The India-Bangladesh Wall: Lessons for Trump," *The Diplomat,* February 15, 2017, *https*://thediplomat.com/2017/02/the-india-bangladesh-wall-lessons-for-trump/.
[333] Ibid.
[334] T.S. Murty and R.A. Flather, "Impact of Storm Surges in the Bay of Bengal," *Journal of Coastal Research* 12 (1994): 149-161.
[335] Ibid.

many "re-curve" and make landfall in Bangladesh.[336] Over the past fifty years, "a storm with hurricane intensity has hit the coast of the Bay of Bengal every 1.5 years."[337]

Bangladesh is also more susceptible to storm surges due to its topography, lying on an exceptionally shallow continental shelf.[338] Because the shelf does not absorb the impact of the surge, waves climb further past the shoreline, and with greater force, than they would otherwise. (Steep continental shelves bear the brunt of a surge, dissipating its force and decreasing its overall height.)[339] Bangladesh is also extremely flat; only about 10 percent of Bangladesh is one meter or more above mean sea level.[340] This lack of topographical variation means that even a relatively small surge can reach far inland. In some cases, the force may dissipate quickly overland. However, even a fast-dissipating storm surge is capable of causing saltwater inundation, thereby damaging or destroying crops.

Moreover, 80 percent of Bangladeshi land is within the floodplains of the Ganges, Brahmaputra, and Meghna rivers. Storm surges use these vast river networks as highways to move inland. In western Bangladesh alone, six major estuarine rivers measure several kilometers across, which is sufficient breadth to allow surges to progress upriver.[341] As surges move upriver, riverbanks are made susceptible to lateral flooding where water pours over the riverbanks.[342] Lateral surge flooding can affect areas well beyond the reach of the direct surge; it has been recorded 60 km inland. Direct surges are limited to a few kilometers from the coastline as they dissipate with land cover resistance.[343] Exceptionally high tides can compound this.

Forty million people, roughly one quarter of Bangladesh's population, live within 100 km of the coast, and this population is continuing to grow. By 2100, it is estimated that thirty to forty million people living in coastal regions surrounding the Bay of Bengal will be at risk of losing their homes to inundation.[344, 345] These coastal populations are highly concentrated.[346] Exposed districts of the Ganges Tidal Plain are defined as experiencing high tidal fluctuations, salinity intrusions and a high risk of cyclones.[347] With such a large population concentrated near the coastlines, even small surges can have massive social impacts.

In addition to directly threatening human populations, storm surges are detrimental to Bangladesh's environment. Surges inundate vast tracts of land with salt water, polluting freshwater resources. Already buckling under the strain of a massive population, saltwater intrusion would

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[336] Ibid.
[337] Hossain, "Climatic Hazards."
[338] Murty, "Impact of Storm Surges."
[339] Ibid.
[340] Mohammed Fazlul Karim and Nobuo Mimura, "Impacts of Climate Change and Sea-Level Rise on Cyclonic Storm Surge Floods in Bangladesh," *Global Environmental Change* 18, no. 3 (2008): 490-500.
[341] Ibid.
[342] Ibid.
[343] Ibid.
[344] Hossain, "Climatic Hazards."
[345] Poh Poh Wong, "Adaptation Policies in the Coastal Zones of the Indian Ocean Region: Challenges, Opportunities, and Strategies" in *Coastal Zones and Climate Change*, eds. David Michel and Amit Pandya, *The Henry L. Stimson Center*, 2010, https://www.stimson.org/sites/default/files/file-attachments/Poh_1.pdf.
[346] Karim, "Impacts of Climate Change."
[347] Ibid.

further diminish Bangladesh's drinking water resources and food stocks.[348] Surges pollute irrigation infrastructure with salt water too, rendering these freshwater delivery systems ineffective. Despite a 20.5 percent increase in irrigated land surface between 1992 and 2003, estimates predict that 15-20 percent of arable land will be covered in saltwater by 2030, cutting off a vast source of food supplies.[349] Furthermore, these increased soil moisture levels will create drainage congestion for the region, adversely affecting rice production in inundated areas. Valuable agricultural land along the coast is expected to be lost to erosion, further reducing Bangladesh's capacity to grow food, and waterlogging (oversaturation of the soil that prevents plants from properly respiring through their root systems[350]) can also prevent or hinder agriculture.[351]

Saltwater intrusion threatens not only agriculture, but also fish and shrimp aquaculture industries, whose growth in recent years has increased many Bangladeshis' standard of living. Fish production more than doubled in Bangladesh between the years of 1984 and 2006;[352] in 2007 alone, Bangladesh exported over $500 million worth of frozen or processed fish, of which shrimp was the dominant export.[353] The destruction of these industries would threaten these peoples' livelihoods.

Effects of Climate Change

As the Earth warms, so do the seas. Oceans temperatures heavily influence the formation and intensity of cyclones by increasing the amount of thermal energy in the upper ocean waters over which cyclones form. Theoretically, as sea surface temperatures increase, the frequency as well as intensity of cyclones should increase as well—a phenomenon discussed in previous sections in this monograph surrounding hurricanes in the United States. Also discussed in that section is the threat of sea level rise to compound storm surges, thus endangering cyclone-prone coasts including Bangladesh.

Although Bangladesh has historically been subjected to cyclones and storm surges, the unpredictable and severe effects of climate change will likely make these storms worse. It is worth noting that while sea levels are rising globally, they do not rise evenly worldwide and will vary regionally based on factors such as regional heating, whether the landmass sinks or rebounds, prevailing winds and ocean currents, proximity to a source of meltwater, and changes in the gravitational pull of seawater. The coastal regions of Bangladesh are experiencing some of the fastest rates of sea level rise in the world. At three points along the Bangladeshi coast, Hiron Point, Char Changa, and Cox's Bazar, sea levels have been rising at a rate of 4.0, 6.0, and 7.8 mm per year, respectively; this is decidedly higher than the global average of 3.2 mm per year.[354, 355] A 30-

[348] Hossain, "Climatic Hazards."
[349] Ibid.
[350] Derk Bakker, "Water-Logging," S*oil Quality.org*, accessed March 27, 2018, https://s3.amazonaws.com/soilquality-production/fact_sheets/18/original/Phys_-_Waterlogging_web.pdf.
[351] Ibid.
[352] Hossain, "Climatic Hazards."
[353] Ibid.
[354] Karim, "Impacts of Climate Change."
[355] "Global Climate Change Vitals of the Planet: Sea Level," *U.S. National Aeronautics and Space Association, Jet Propulsion Laboratory,* last updated December 2017, accessed March 28, 2018, https://climate.nasa.gov/vital-signs/sea-level/.

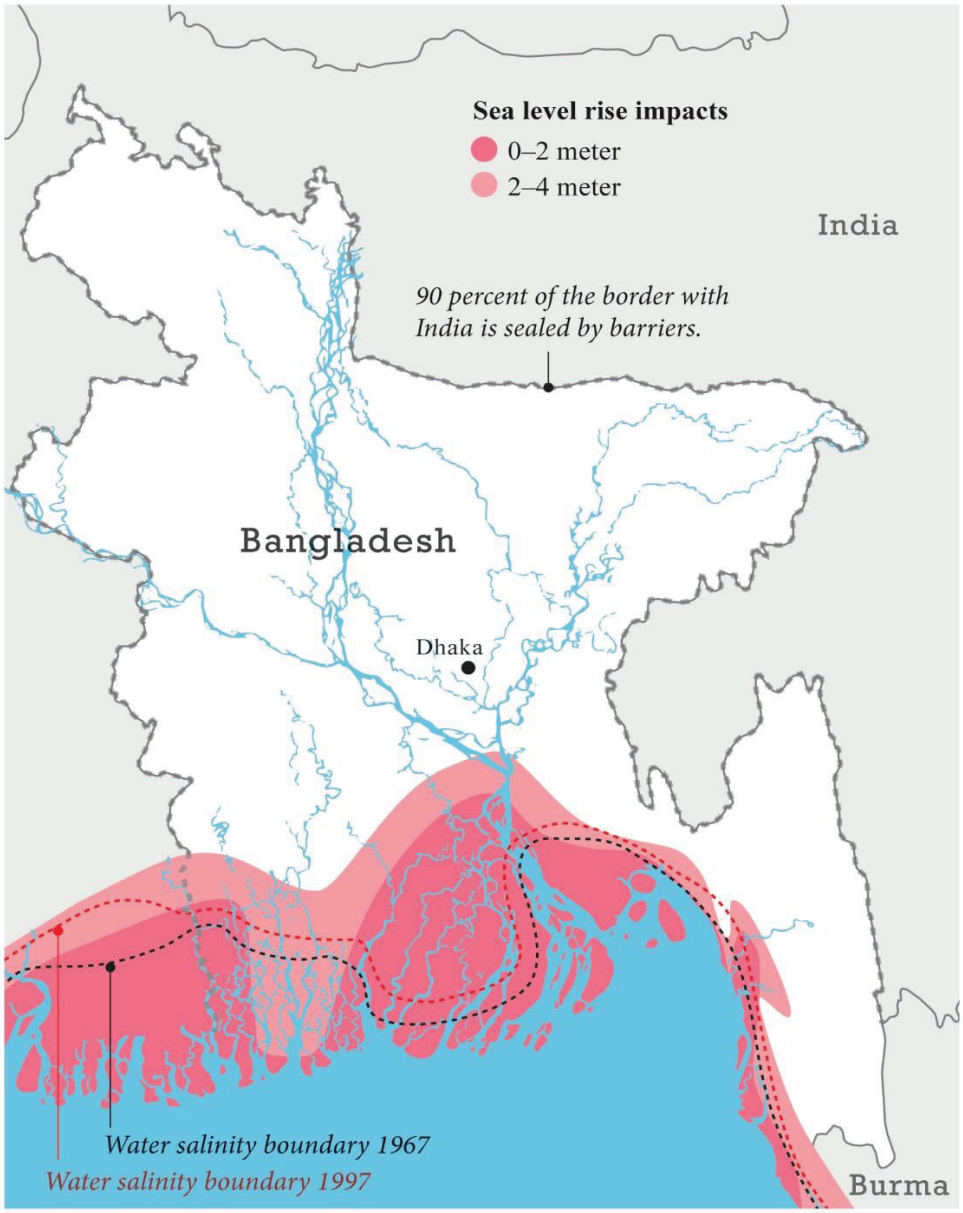
45 cm rise in sea level (well within the predictions for the end of the century) could displace more than 35 million coastal Bangladeshis.[356] Higher sea levels mean that storm surges have the capacity to travel further inland and subsequently cause even more destruction. Furthermore, rising sea levels will displace millions of individuals within Bangladesh as even a 10 cm rise in sea level, expected by 2030, would flood 2,500 km² along the coast.[357] With a one-meter rise, expected later in the century, districts located within 50-60 km of the coastal belt, in addition to Bangladesh's heavily populated offshore islands, will be inundated.[358]

The following figure shows the effect of a one to four-meter rise (3.28—13.12ft) in sea level and the corresponding encroachment of the salinity boundary along Bangladesh's coastline (areas below salinity boundary will no longer be able to produce agriculture). A rise of 1.5 meters (4.92ft), which is within the range of some predictions by 2100, would inundate 22,000 square kilometers (8,494.25 square miles) and would render 17 million Bangladeshi citizens internally displaced people or refugees.[359]

[356] "Vulnerability, Risk Reduction, and Adaptation to Climate Change: Bangladesh," *The World Bank*, April 2011, http://sdwebx.worldbank.org/climateportalb/doc/GFDRRCountryProfiles/wb_gfdrr_climate_change_country_profile_for_BGD.pdf.
[357] Hossain, "Climatic Hazards."
[358] Ibid.
[359] Sahana Bose, "Sea-level Rise and Population Displacement in Bangladesh: Impact on India," *Maritime Affairs: Journal of the National Maritime Foundation of India* 9, no. 2 (2013): 62-81.

Vulnerability of Bangladesh

Rise of 1.5m means 17 million environmental refugees



Source: Yeoneu Architects

India-Bangladesh Relations

Due to sea level rise and the increased ferocity of storm surges, food insecurity in Bangladesh is likely to become particularly problematic and millions may be displaced or forced to emigrate. It is likely that most of these Bangladeshi refugees will go to India because they share a large border area. India has been dealing with the immigration of undocumented Bangladeshis since the 1980s. Thousands of Bangladeshis migrated illegally to India during that decade to escape the poor economic conditions of their home country. This migration was not met with open arms; there were mass killings of Bangladeshis in the Indian state of Assam. This marked the first time that Indian officials proposed a border fence between India and Bangladesh, furthering the contentious nature of bilateral relations between the two South Asian states.

As of March 2017, nearly 3,700 km of fencing has been completed by India's government, covering about 90 percent of the border between the two countries. Efforts to seal off the remaining 10 percent of the border to obstruct the flow of Bangladeshi migrants into India have been slowed by "very difficult terrain," but the Indian government plans to complete the border fence by the end of 2018.[360] The fence is as high as nine meters in some places, and is covered with barbed wire.[361]

The Border Security Force (BSF), charged by India with patrolling the border zone, has demonstrated a propensity for violence, intermittently increasing friction between the two states. Several killings along the border have been credited with stirring an anti-Indian sentiment in Bangladesh, although the two countries have been moving towards a more friendly relationship in recent years.[362]

The fencing has also made life complicated for those who live along the border. New Delhi's recent decision to honor Dhaka's request for a larger buffer between the fence and the actual border means that about 7,123 families will lose their homes, lands, or shops in the tiny Indian state of Tripura alone.[363] In September of 2015, an estimated 1,000 villagers protested the resuming of the border fence construction.[364] According to the Secretary of the Tripura Chamber of Commerce, "the fence has prevented [the] flow of commodities like fish and other food items. That affects the poor and the middle class on both sides. But it has not stopped [the] flow of high-value contraband…"[365] Migration and the policies seeking to stem it have adversely effected both countries' populations along their mutual border—signaling a need to seek new solutions as climate change threatens to displace more people in the region.

Fencing off the Bangladeshi border is will likely not be a sustainable long-term solution for either India or Bangladesh. As the situation in Bangladesh worsens due to climate change and

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[360] Huizhong Wu, "India Wants to Seal Its Border with Pakistan and Bangladesh," *CNN*, March 29, 2017, http://www.cnn.com/2017/03/28/asia/india-pakistan-bangladesh-borders/index.html.
[361] Bappa Majumdar, "Border Fence Draws Barbs from Trapped Indian Farmers," April 30, 2007, https://www.reuters.com/article/us-walls-india/border-fence-draws-barbs-from-trapped-indian-farmers-idUSDEL20663420070430.
[362] Nilanjana Bhowmick, "Border Violence Tests Fragile Peace on India-Bangladesh Frontier," *Time*, January 27, 2012, http://world.time.com/2012/01/27/border-violence-tests-fragile-peace-on-india-bangladesh-frontier/.
[363] Ibid.
[364] Ibid.
[365] Ibid.

migrants are forced to flee the rising sea and economic dislocation that comes with it, there simply will not be enough land or suitable employment to sustain the Bangladeshi population within its borders. Whether India likes it or not, Bangladesh cannot be ignored and its problems will soon become India's. It is therefore in the best interest of both countries to work together in addressing trans-boundary issues like climate change.

Beyond the obvious regional implications of a potential conflict between Bangladesh and India, migratory movements caused by climate change have important implications for U.S. foreign policy. Such large movements of people could potentially lead to political instability in India, a key ally of the United States in Asia, as well as other countries of the region, creating instability in one of the world's most populous regions. However, states that violate human rights in the pursuit of improving border security and stemming illegal immigration tarnish their international reputations and diminish their ability to act as effective U.S. partners. The United States should therefore place itself at the forefront of advising its allies in dealing with the effects of migration stemming from sea level rise and other climatic phenomena in a responsible and sustainable manner.

Policy Options

Despite being one of the poorest countries in the world in terms of GDP per capita, there are measures that Bangladesh can take to mitigate the effects of cyclones and storm surges. Firstly, efforts must be made to decrease the direct impact that surges and cyclones have on human lives. As of 2012, 2,023 cyclone shelters have been built along the coastline.[366] These edifices have multiple stories, and allow for hundreds of people to cluster in and on top of them while the surge passes underneath. Yet, in order to make sure people reach these shelters, the existing early cyclone warning system must be enhanced. Bangladesh currently has an early warning system in place but it fails to do two things: reach every citizen who is at risk, and convey the need to evacuate.[367] Bangladesh has been experimenting with community-level warning systems, rather than a national level system in order to address these issues. This effort must be expanded so that everyone may reach the cyclone shelters in time. Furthermore, these warning services must establish credibility with the populace. During the 1991 cyclone, of the individuals who did not seek shelter, 70 percent did not believe the warning, or that a cyclone or surge of the expected magnitude would transpire.[368] Trust in the community or national level warning systems is imperative to save lives during cyclone season.

Enhanced infrastructure could help mitigate the impact of the surges as well. As of 2012, a total of 3,931 km of coastal embankments have been built by the Bangladeshi government and foreign donors in order to protect coastal land from inundation. Another 4,774 km of drainage canals serve the same purpose.[369] Yet more must be built to bear the brunt of these storms. Protecting farmland and drinking resources from saltwater intrusion is essential to food security, and doing so will help prevent migration that may cause social strife and conflicts. Despite the high cost of infrastructure projects, the government recorded a budget surplus of just under 4

[366] Tiffany Bisson, "An Assessment of Cyclone Mitigation and Management Policies of Bangladesh: A Focus on Early Warning Systems," *University of Manitoba*, February 2012, https://mspace.lib.umanitoba.ca/bitstream/handle/1993/5331/Bisson_Tiffany.pdf?sequence=3&isAllowed=y.
[367] Ibid.
[368] Ibid.
[369] Ibid.

percent of their annual GDP in 2014.[370] This surplus would be well used if devoted to infrastructure projects. Drainage systems and embankments protect not only citizens' lives, but also protect their livelihoods and food security.

Bangladesh's increasing vulnerability to climate change is also a call to action for the international community. Although Bangladesh's concerns as a flat, low-lying nation are unique, it is not alone in its position as a developing nation struggling to combat the effects of a climate it had little part in affecting. Nations without the capital or ability to address their climate concerns would benefit enormously from aid coming from the wealthier, historically high-emitting countries that share a disproportionately large responsibility for the anthropogenic greenhouse gases that have precipitated climate change. Climate change knows no borders, and the burden of mitigation and humanitarian assistance will ultimately fall upon the wealthier members of the international community, while localities should shoulder the initiatives within their own states. Bangladesh has the enormous task of tackling its own environmental issues, but other nations should not be so myopic as to believe under-developed countries will be able to solely and continuously battle a threat with no clear end in sight.

[370] "Bangladesh Government Budget," *Trading Economics*, last modified 2015, accessed March 20, 2018, http://www.tradingeconomics.com/bangladesh/government-budget.

Chapter 9: Effects of Sea Level Rise on River Basins

While Chapter 3 discusses the freshwater issues in the upstream portion of the Nile, the downstream river and its water resources are threatened by saltwater intrusion from the rising Mediterranean Sea. In the Nile River Basin, sea level rise will most directly impact Egypt given its coastal location and reliance on the river's delta. The Nile Delta aquifer is one of the largest groundwater reservoirs in the world, underlying about three million acres of fertile land.[371] Rising seas pose a severe threat to the country's freshwater supplies as saline seawater creeps inland, intruding on Egypt's underground aquifers. By 2100, as much as 60 percent of the Nile Delta region is predicted to be saturated with salt to the point of approaching infertility, and 20 percent completely inundated by the sea.[372] This will threaten both the crops that are necessary to feed the growing Egyptian population as well as fresh water. Additionally, the country's coastal cities are built on low-lying land and sea level rise between 0.5 and 1 meter could put large areas of Alexandria, Damietta, Beheira, and Port Said partially underwater, displacing millions and destroying much of the region's agriculture."[373]

The threat of rising sea levels is putting additional pressure on Egypt to resolve water allocation disputes while simultaneously protecting the historical flow of the Nile River. This is a difficult—if not impossible—task that is forcing Egypt to choose between peace and survival. As the flow of the Nile River decreases and aquifers in the region dry up, the process of saltwater intrusion will only accelerate and become more severe.[374] Therefore, even if Egypt could find a way to reduce freshwater demand and consumption within its borders, increased demand for the Nile's resources upriver would still worsen the effects of sea level rise along the lower Nile Delta and coastal regions. For Egypt, some of the negative effects of climate change and sea level rise

[371]Ahmed Sefelnasr and Mohsen Sherif, "Impacts of Seawater Rise on Seawater Intrusion in the Nile Delta Aquifer, Egypt," *Groundwater* 52, no. 2 (2014): 264-76.
[372] Emily Crane Linn, "Egypt's Nile River Delta is Sinking into the Sea," *Mother Jones*, November 23, 2015, https://www.motherjones.com/environment/2015/11/egypt-nile-river-climate-change/.
[373] Ayman F. Batisha, "Adaptation of Sea Level Rise in Nile Delta Due to Climate Change," *Earth Science & Climate Change* 3, no. 2 (2012), https://www.omicsonline.org/adaptation-of-sea-level-rise-in-nile-delta-due-to-climate-change-2157-7617.1000114.pdf.
[374] Sefelnasr, "Impacts of Seawater Rise on Seawater Intrusion in the Nile Delta Aquifer."

are unavoidable, but effective policies and cooperation can reduce the severity and the speed of change. Without cooperation and compromise among Nile Delta states, Egypt will face the most severe and immediate effects of climate change and rising sea levels.

Climate change will become an increasingly difficult challenge for the Egyptian government in the coming years. Cairo must simultaneously maintain internal stability while combatting the rising seas to its north and threats to its water supplies from Ethiopia and other upriver Nile Basin states to its south. There may no good solutions to this problem for Egypt. They must choose between negotiating with Ethiopia and the other riparian states from a position of weakness, or commit to direct conflict that could destabilize the region and have costly political and socio-economic ramifications. There is a significant need for the Nile Basin states to find an agreeable solution to the allocation of finite freshwater resources, especially if they want to avoid the environmental problems that will only be made worse by inaction and climate change. The challenges confronting the Nile demonstrate the need for all states that are faced with growing freshwater scarcity to work collectively, cooperatively, and proactively to achieve mutually-beneficial aims. Otherwise, these states may find themselves facing a future of ever more dire circumstances, rising political tensions, and potentially interstate conflict.

The following figure shows the effects of a 1 meter (3.28 ft.) increase in sea level along Egypt's Mediterranean Coast, which is predicted by 2100. Under these conditions, seawater would inundate major Egyptian cities such as Alexandria, Dumyat, Port Said, and Damanhur (pink shading). Any further increase in sea level above one meter, from either storm surge or further melting of glacial ice sheets, could inundate cities such as Kafr el Shihk and El Mansura as well as much of the Northern Nile basin. Aside from these scenarios, losses of freshwater wells and aquifers will be apparent long before these cities are inundated, as the sea encroaches from beneath the bedrock and pushes salt water into freshwater stores.

Impact of 1 Meter Sea Level Rise on the Nile Delta

Source: Mohamed Hereher, Damietta University

Impact of Rising Sea Levels on Analogous River Deltas

To understand the Nile Delta's importance, it is helpful to recognize the crucial role that all river deltas play in the environment. Deltas are rich deposits of sediment that provide important nutrients to the surrounding areas. Thus, deltas have historically been great centers of agriculture and hubs for economic development and the growth of cities. Indeed, the delta at the intersection of the Tigris and Euphrates Rivers, in modern-day Iraq, gave rise to the earliest known civilization. At the same time, "deltas are widely recognized as being highly vulnerable to the impacts of climate change, particularly sea-level rise and changes in runoff, as well as being subject to stresses imposed by human modification of catchment and delta plain land use."[375] Add to this the fact that delta plains are "densely populated and large numbers of people are often impacted as a result of external terrestrial influences (river floods, sediment starvation) and/or external marine influences (storm surges, erosion)."[376]

Case studies of the Mississippi River Basin, Mekong Basin, and Indus River Basin serve as useful comparisons to the Nile region, specifically to demonstrate the effects of climate change events. Hurricane Katrina, damaged 388 square kilometers of coastal wetlands, levees, and islands around New Orleans in the Mississippi River delta region.[377] The loss of these wetlands has affected the habitats of various animals, decreased U.S. fisheries' production, and left the region in a higher state of vulnerability without the wetlands serving as a natural barrier. In addition, billions of dollars in homes, historic structures, and other buildings were lost—not to mention the massive loss of life. As is now well-known, studies of the protective levee system had shown growing vulnerabilities to flooding. Indeed, storm surge surmounted the city's 4.5-meter levees, flooding 75 percent of New Orleans, with over half of the city's structures inundated at least 1.2 meters below the waves.[378]

The Mekong Basin in Southeast Asia is another extremely vulnerable delta region similar to the Nile. This region is particularly susceptible to climate change and sea level rise because of the construction of dams, which reduce the supply of sediment to deltas. A reduction in sediment to the delta causes it to sink, compounding the issue of a rising sea. This is an issue that the Nile Basin states must deal with as well due to the existence of the Aswan High Dam and the ongoing construction of the Grand Ethiopian Renaissance Dam. Furthermore, the Mekong Basin's high level of human activity increases the threat level. Fisheries play a central role in peoples' lives, particularly the rural poor; sixty percent or more of the population in countries downstream along the Mekong River, like Laos and Cambodia, are economically involved with fisheries.[379] Changes in sea level and flooding will change the water flow through the basin and threaten the diverse fish population with salt water. For example,

> Can Tho, a city of 1.1 million people in southern Vietnam, is located just 0.8 meters above sea level and has always depended on flood cycles to grow crops. More than half of Vietnam's rice is produced in this region, as well as 60 percent of its fish and shrimp. Experts warn there is a possibility that sea levels will rise in the delta region around Can

[375] M.L. Parry et al., "Cross-Chapter Case Study," in *Climate Change 2007: Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, (Cambridge: Cambridge University Press, 2007), 843-868.
[376] Ibid.
[377] Ibid.
[378] Ibid.
[379] Ibid.

Tho causing devastating floods that will displace millions and destroy those crops.[380] The livelihood of local people is dependent on fishing just as those living in the Nile River Basin are dependent on agriculture.

Finally, the Indus River Basin in Pakistan and India has demonstrated the level of destruction that can ensue when multiple environmental stressors come together. In the summer of 2010, the torrential rains that fell on Pakistan led to massive flooding that "submerged a fifth of the country and displaced millions—constitut[ing] the worst natural disaster to date attributable to climate change" as of 2010.[381] Pakistan's environmental troubles are numerous, with record temperatures, monsoons, drought, and glacial melt all contributing to a complex and dangerous series of natural disasters.[382] Furthermore, the destructiveness of flooding in Pakistan is exacerbated by widespread deforestation, much of which has occurred at the hands of the Pakistani Taliban, which uses profits from logging to finance its operations. In fact, Pakistan has the highest annual rate of deforestation in Asia—only two percent of the country's total area remains forested today.[383]

Saltwater intrusion from the Indian Ocean poses another serious threat to Pakistan. "As a result of upstream water abstraction, mainly for irrigation, by the time the Indus reaches the Kotri Barrage (some two thirds of the way into Sindh Province, or 200 km from the Arabian Sea), there is inadequate flow to maintain the natural ecosystems of the Indus Delta," and consequently severe saltwater intrusion occurs.[384] Land in the area has become unsuitable for agriculture, and drinkable water sources have become very scarce or have disappeared altogether. In Thatta, a predominantly agricultural district in Pakistan's Sindh Province, almost one-third of land has been affected by saltwater intrusion.[385]

These climate conditions are directly linked to security. For example, as is the case in the Nile Delta, there are disagreements between Pakistan and India regarding the flow of the Indus River (see Chapter 6 for a detailed discussion of this case). Some in Pakistan argue that India, their upstream riparian neighbor, manipulates the flow of water downstream, which leads to flooding. Furthermore, as in Egypt and Syria, environmental stresses could worsen Pakistan's urban violence as disasters and shortages displace rural farmers, forcing them to migrate to the cities. A final troubling issue is that Pakistan's environmental insecurity could endanger its nuclear security. According to *Foreign Policy* magazine,

> [t]he fear here is not of militants seizing nuclear weapons, but rather of the nation experiencing the type of disaster that befell Japan's Fukushima Daiichi nuclear plant in March 2011. The Karachi Nuclear Power Plant (KANUPP) in Pakistan sits not only in a

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[380] "Vietnam: Sea-Level Rise Could 'Displace Millions,'" *IRIN News*, May 20, 2011, www.irinnews.org/Report/92763/VIETNAM-Sea-level-rise-could-displace-millions, Accessed February 13 2013.
[381] Michael Kugelman, "Pakistan's Climate Change Challenge," *Foreign Policy*, May 9, 2012, http://afpak.foreignpolicy.com/posts/2012/05/09/pakistans_climate_change_challenge.
[382] Ibid.
[383] Ibid.
[384] Lucy Emerton, *Values and Rewards: Counting and Capturing Ecosystem Water Services for Sustainable Development* (Cambridge: The World Conservation Union, 2005).
[385] "The World Conservation Union Quarterly Newsletter: Valuing Coastal Ecosystems," *International Union for Conservation of Nature and Natural Resources*, April 2007, http://cmsdata.iucn.org/downloads/4th_newsletter.pdf.

> flood- and storm-prone area, but also in one of the most densely-populated parts of the country.[386]

Pakistan has been working on national strategies to deal with these climate change events, which will continue to pose future threats. Nevertheless, the past two years show plenty of evidence of how climate change can ravage a country.

The modern hurdles facing other delta-dependent countries should inspire those in the Nile region to be proactive in dealing with their own issues in order to escape a similar fate. A picture of rising sea levels as a global destabilizing force emerges. The phenomenon is likely to produce new disputes in regions already plagued by endemic instability. Analyzing the future security consequences of such conflicts in terms of U.S. interests will be key in creating an effective foreign policy. Climate change must be included in the analytical basis for making future policy decisions.

Policy Options

There are no silver bullets to the problem of rising sea level and more severe storm surge along the coast of Egypt or other river deltas. Numerous factors including; geography, geological context, population density, financial and technical resources, and even political inclinations play a role in determining the most cost-effective and realistic method for reducing flooding vulnerabilities and fresh water access in a given region. Under the best of circumstances where geography and geology is optimal, financial and technical resources are plentiful, and political consensus exists to address the threat, there still exist numerous options to improve a region or city's resilience. Under such optimal circumstances a combination of natural barriers like sand berms and wetlands can be developed alongside manmade infrastructure like levees and sea walls in order to protect property, infrastructure, residential populations, and preserve vulnerable land and waterways.

However, under most circumstances geography and sediment characteristics are less than optimal if not extremely problematic, access to financial and technical resources are limited, and political consensus is often lacking or governance itself is either incapable or unwilling to address the issue. Under such suboptimal circumstances, options are much more limited and even reaching an agreement or implementing a plan becomes problematic. However, there are a variety of options such as the limited development of natural sea barriers and infrastructure to protect vital regions and facilities; the relocation of vulnerable populations to higher ground; regional coordination and international backing to improve resiliency; switching to agricultural products that are more tolerant of seawater in vulnerable areas; planting less water intensive and more resilient crops across the entire region; developing alternative means of employment for citizens dislocated from flooded regions; improving building regulations; limiting development in flood prone areas; rerouting of alternative freshwater sources; filling or draining of vulnerable aquifers; and developing desalination infrastructure. While none of the options will necessarily eliminate the threats from rising sea level and more severe storm surges, they can help to reduce the severity of the impact and improve overall resiliency.

[386] Kugelman, "Pakistan's Climate Change Challenge."

Chapter 10: Alaska and the Arctic

Alaska

Located at the most northwestern reaches of the United States, Alaska provides additional examples of the trouble warming temperatures will bring to coastal areas of the country. Alaska is an unusual case because of the highly varied effects that climate change is having on sea levels in different parts of the state. In remote northern coastal villages on the Arctic and Bering coasts, sea level rise poses a grave threat as it raises the launching pad for surge waves from severe winter storms. Meanwhile, the southern coast of the state faces the opposite problem: melting glaciers are leading to geological processes causing land to rise much faster than the sea, which creates its own disruptive effects.

First, there is the threat of sea level rise: Alaska has warmed twice as fast as the continental United States,[387] leading to rapidly rising seas as warming water expands and glaciers melt. Regional sea level rise can differ from the global average due to any number of factors including, but not limited to, regional heating, sinking or rebound of landmass, prevailing winds and ocean currents, proximity to a source of meltwater, or changes in the gravitational pull of seawater. A second threat to Alaska is its rapidly thawing permafrost that many settlements are built upon, which is causing buildings to sink and accelerating erosion—further increasing the pace of the advancing waters. A third growing threat is the decreasing extent of sea ice, increasingly exposing towns to more frequent and more intense storm waves, as communities lose the protective dampening effects of pack ice. Climatic shifts are also increasing the frequency and intensity of storms that batter these increasingly vulnerable communities.[388]

In the harsh northern and western regions of Alaska, many villages are located coastally, along the Bering Sea and Arctic Ocean. Many of these settlements are Native Alaskan communities that are often highly reliant on fishing and are greatly impacted by changing in sea ice conditions. These towns are currently under threat from several climate-related processes. In some cases this extends beyond economic damages, daily disruptions, and saltwater intrusion to

[387] Suzanne Goldenberg, "America's Climate Refugees," *The Guardian,* May 13, 2013, http://www.theguardian.com/environment/interactive/2013/may/13/newtok-alaska-climate-change-refugees.
[388] "Sea Level Rise and Storm Surge," *Alaska Sea Grant, College of Fisheries and Ocean Sciences at the University of Alaska Fairbanks,* https://seagrant.uaf.edu/map/climate/docs/sea-level.php.

endanger the survival of several towns, such as Newtok, Kivalina, and Shishmaref, which are preparing to relocate.[389] Such towns could be washed away entirely within the next few years. As is so often the case with climate change, the places that are most at risk are also least equipped to deal with its effects: these tiny, economically-isolated communities face costs of up to $200 million to relocate,[390] leaving them dependent on government intervention. Additionally, traditional tactics such as the construction of sea walls and levees are often impractical, due to both the cost and the soft, porous soil that melting permafrost leaves behind.

However, as warming progresses, many additional villages will come under threat. A GAO report from 2003 declared over 180 villages, comprising 86 percent of Alaskan Native communities, to be ultimately under threat from rising seas and erosion.[391] Government officials found that 31 of those communities faced 'imminent' danger.[392] Many of them exist in harsh, remote locations, and in the face of added stresses from flooding, storm damage, land loss, and ecological damage, their prospects for future survival, and with them, the continuity of Alaskan Native communities and cultural heritage, are tenuous.

Meanwhile, in southern Alaska, land in coastal areas is rising at two to four times the rate of the absolute sea level, meaning that the relative sea level is actually falling, with significant effects.[393] This rise is caused by geological processes that are related to both long-term trends and the recent rapid retreat of Alaska's land glaciers. The land in southern Alaska is thought to have been rising over the long term as a result of shifts by plate tectonics. Alaska is located near the convergence point of the Pacific and North American plates, and as the Pacific plate is forced under the North American, land buckles upward. Additionally, since the end of the last Ice Age, a process known as isostatic rebound[394]—wherein land formerly compressed by the weight of glaciers lifts when they melt—has been contributing to the land rise. Isostatic rebound has further accelerated as existing glaciers have melted rapidly since the onset of anthropogenic warming.[395] As a result, the land has risen up to three meters (10 feet) in the last 200 years, with at least another meter (three feet) of rise expected by the year 2100.[396]

While land rise seems less dramatic than tales of sinking towns, its effects are disruptive in their own ways. Waterways dry up and formerly navigable channels become impassable, wreaking havoc on both ecological processes (like the all-important salmon runs), and marine industries, like fishing. Additionally, valuable habitats like wetlands are drying out. While land rise lacks the sudden and dramatic consequences of severe flooding and potential inundation, it is a reminder that the damages of climate change are highly varied by locale. Therefore, in order to

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[389] Erica Goode, "A Wrenching Choice for Alaska Towns in the Path of Climate Change," *The New York Times*, November 29, 2016, https://www.nytimes.com/interactive/2016/11/29/science/alaska-global-warming.html.
[390] Ibid.
[391] "Alaska Native Villages: Most are Affected by Warming and Erosion, but Few Qualify for Federal Assistance," *U.S. Government Accountability Office,* December 12, 2003, http://www.gao.gov/products/GAO-04-142.
[392] Goode, "A Wrenching Choice for Alaska Towns."
[393] Doug O'Harra, "Southern Alaskan Sea Levels Defy Worldwide Trends," *Alaska Dispatch News,* December 27, 2010, http://www.adn.com/alaska-news/article/southern-alaskan-sea-levels-defy-worldwide-trends/2010/12/28.
[394] "Sea Level Rise and Storm Surge," *Sea Grant Alaska*.
[395] Cornelia Dean, "As Alaska Glaciers Melt, It's Land That's Rising," *The New York Times,* May 18, 2009, http://www.nytimes.com/2009/05/18/science/earth/18juneau.html?_r=0.
[396] Ibid.

successfully adapt to climate changes it is essential that regional variation accounted for and understood.

The Melting Arctic

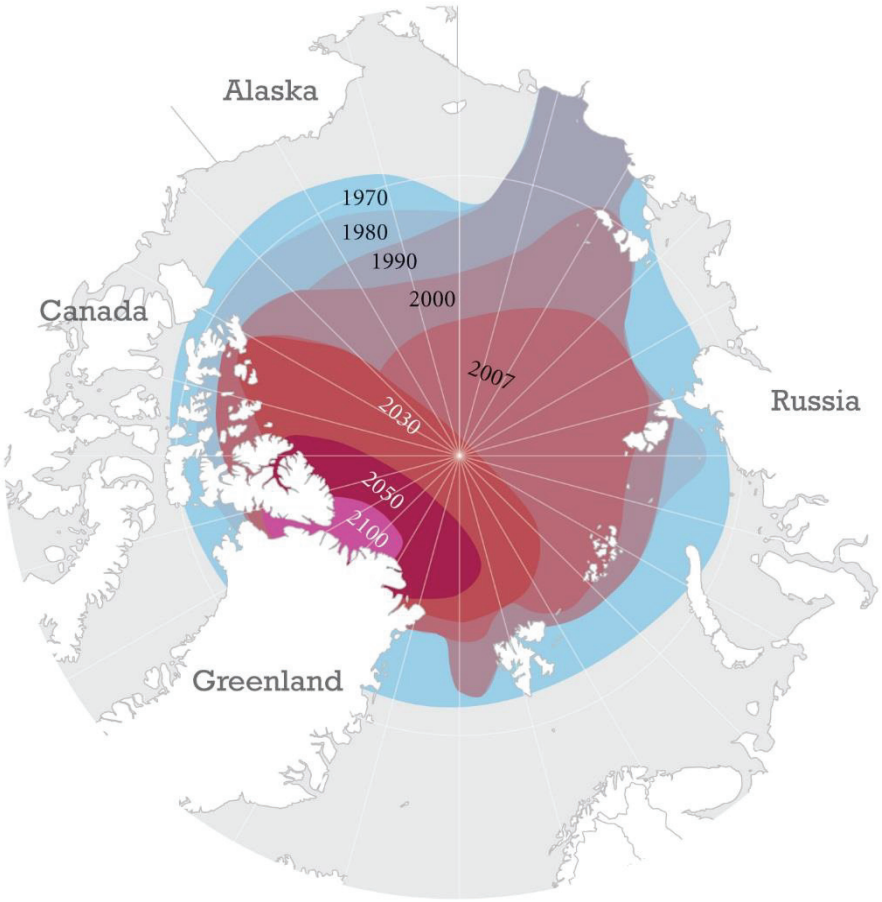
Just north of Alaska, melting sea ice is creating a host of new security challenges and opportunities. The accelerated warming in Alaska extends to the Arctic Ocean, with a host of important environmental and ecological consequences. At the same time, however, it could open up a host of new spaces that could significantly change the security dynamics of the region.

Temperatures in the Arctic are changing faster than in any other region in the world. Since 1951, the Arctic has warmed roughly twice as fast as the global average.[397] While some of the region is still extremely cold in the summertime, many areas hover right around 0°C. Therefore, even a slight warming can push the temperature above the melting point and thaw sea ice and glaciers. Decline in sea ice as temperatures rise reinforces a feedback loop known as the Albedo effect, which drives further warming and even greater reductions in sea ice. Essentially, as highly-reflective sea ice melts, sunlight that would have otherwise been reflected back into space is instead absorbed by dark seawater. This contributes to both atmospheric and oceanic warming and even further accelerates ice loss. Thus, the general warming contributes to sea-level rise globally via two main pathways: the thermal expansion of warmer waters, and the addition of water volume through melting of otherwise buttressed or land-elevated ice. Additionally, decreased ice coverage has had a number of deleterious effects on the wildlife of the region, with a variety of ecological consequences.[398]

The following figure shows the reduction in size of Arctic sea ice extent from 1970 to the 2000's and projections of further reductions through 2100. The figure provides clear evidence that the Arctic Ice Sheet has already contracted significantly and consistently over the last few decades—a trend that will continue as the Earth further warms.

[397] "The Melting North," *The Economist.*
[398] Christa Marshall, "Arctic Sea Ice Loss Creates Ripple Effect," *Scientific American,* 2013, http://www.scientificamerican.com/article/arctic-sea-ice-loss-creates-ripple-effects.

Shrinking Arctic Ice, 1970-2100



Sources: The Arctic Institute, Weather Underground

In addition to the environmental consequences of Arctic melting, warming trends have opened up vast new spaces in the Arctic Ocean previously impassable because of the presence of sea ice. This leads to the potential for exploitation of newly accessible resource deposits, particularly hydrocarbons, and the development of more efficient trans-Arctic shipping routes.

There are two main shipping avenues in the Arctic: the North Sea Passage from eastern Russia to northern Europe, and the Northwest Passage from the eastern United States to the Bering Sea. Historically, these routes are only open seasonally, and typically require the use of machinery to clear obstructing sea ice during a ship's passage. Each route, with enhanced ease of passage, could shave thousands of kilometers off existing shipping lanes, but their intensive use faces several obstacles. First, the United States is woefully underequipped in terms of icebreaking capabilities to operate a merchant marine fleet in the Arctic Ocean. The United States Coast Guard greatly lags behind other Arctic powers with only two operational icebreakers, while Russia has forty, Finland has seven, and Sweden and Canada each have six.[399] Second, Canada claims the Northwest Passage as its internal waters, and thus any efforts at common use as a shipping route may become entangled in gray areas of international law. Nonetheless, should Arctic shipping become commonplace, the United Staes will need to place a renewed emphasis on maritime security in the Arctic and to invest in Arctic ice-breaking capabilities.

In addition to expanded shipping opportunities, Arctic melting could lead to increased conflict and competition over newly exploitable resources. Massive hydrocarbon reserves, including upwards of 15 percent of the Earth's remaining oil and 30 percent of its natural gas could potentially be extracted as melting continues.[400] Overlapping claims over large energy reserves has increased tensions in the region, particularly between Norway and Russia, as Norwegian exports of gas from Arctic operations have undermined Russia's attempts to use their role as a natural gas supplier as leverage in European politics. Going forward, U.S policy in the Arctic will be best served by clear commitments to and investments in necessary Arctic security infrastructure and efforts to create new institutions with the governance capacities to resolve competing claims, particularly with regard to hydrocarbons.

Alaska has already seen some dramatic and varying effects of climate, the consequence of which have stemmed directly from the physical environmental changes as well as indirectly as economic and social implications from such changes. The consequences of climate change affecting Alaska's citizens and its ecology are currently localized matters that must be addressed as both existing mitigation issues as well as evolving threats requiring adaptation policy. This is in contrast to the national and international consequences of melting Arctic ice in the surrounding and nearby Alaskan waters, which will require a multilateral approach in support of a cooperative, rather than competitive, multinational Arctic presence.

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[399] Christopher Woody, "The US Navy and Coast Guard are Looking to Play Catch-Up in the Arctic," *Business Insider*, October 19, 2017, http://www.businessinsider.com/the-us-navy-and-coast-guard-are-looking-to-play-catch-up-in-the-arctic-2017-10.

[400] Jeremy Bender and Michael Kelley, "Militaries Know That the Arctic Is Melting," *Business Insider,* June 3, 2014, http://www.businessinsider.com/the-competition-for-arctic-resources-2014-6.

Chapter 11: Challenges for the U.S. Eastern Seaboard

Sea level rise has long been recognized as one of the most direct physical threats posed by a changing climate. The potential costs associated with rising waters are significant and varied. The IPCC estimated that the United States could suffer up to 150 billion dollars in damage to coastal properties from rising floodwaters over the next century, even without accounting for increased storm intensity.[401] However, the IPCC's initial estimate may have been too conservative. The Organization for Economic Co-operation and Development found that a conservative estimate of a half meter (20 inches) of sea-level rise by 2070 would put 150 million inhabitants of the world's largest port cities at risk from coastal flooding, along with $35 trillion worth of property, which is an amount equal to 9 percent of the global GDP.[402] In addition to these basic costs of flooding, a wide variety of disruptive effects on infrastructure, military operations, agriculture, water sources, environmental quality, and other economic activities are likely to afflict the United States, and the East Coast in particular, in the coming century.

Although global estimates of sea level rise are important, regional predictions can vary outside of this range and more useful for purposes of implementing adaptive strategies and understanding local risks. It is estimated that sea levels along the Atlantic rim will rise considerably faster than in the Pacific Basin, with the stretch of the United States' East Coast north of Cape Hatteras exhibiting a rise exceeding global averages by three or four-fold—likely attributable to dynamical changes from Greenland meltwaters.[403] This regional sea level rise rate subjects a variety of locations up and down the Eastern Seaboard to increased threat levels as climate change

[401] "Working Group II: Economic Costs of Sea Level Rise," *Intergovernmental Panel on Climate Change*, 2001, http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=298.
[402] Tim Folger, "Rising Seas," *National Geographic*, September 2013, http://www.nationalgeographic.com/magazine/2013/09/rising-seas-coastal-impact-climate-change/.
[403] Kristen French, "Researchers Model Differences in East Coast Sea Level Rise," *Columbia University Earth Institute*, May 18, 2017, http://blogs.ei.columbia.edu/2017/05/18/researchers-model-differences-in-east-coast-sea-level-rise/.

spurs both higher seas [404] and greater intensity in oceanic storm systems. [405] Both these developments will intensify flooding risks in large portions of the relatively low-lying Eastern Seaboard.

Compounding the problem of rising seas on the U.S. East Coast is a long-running geological process known as "subsidence" that causes land to 'sink' independently of sea level rise at rates approaching one inch per decade.[406] Significant disruptions have already occurred as a result of rising seas and sinking land. Since 1950, absolute sea levels across the East Coast have risen by up to twenty centimeters (eight inches),[407] leading to more flooding events, degradation of beaches, wetlands, and coastal infrastructure, and greater vulnerability to storm surge events. For example, in Norfolk, Virginia, flooding has increased two or three-fold since 1980, and flooding now often occurs simply as a result of daily tides.[408] It is also thought that rising seas have played a significant role in the increasing levels of damage inflicted by oceanic storm systems in the eastern United States.[409]

Sea level rise on the East Coast of the United States is of particular concern because, unlike many of the heretofore discussed issues, which often focus on the 'knock-on' effects connected in subtler ways to climate-related disruptions, it poses a direct physical threat to the infrastructure, military installations and hardware, force capabilities, and human security of swathes of the American homeland. There are innumerable locales along the Atlantic coast where the effects of rising seas will be apparent, but it will be illuminating to focus on five particular regions: The New York-Newark metropolitan area in the northeast, the Hampton Roads region in southeastern Virginia, Louisiana, the region of southeast Florida centered about Miami, Alaska, and the Arctic. Each of these regions faces distinct challenges as a result of coming sea-level rises.

Miami and South Florida

In April 2012, the U.S. Senate Committee on Energy and Natural Resources convened a hearing dedicated to examining the effects of sea level rise. According to Benjamin H. Strauss, COO and Director of Climate Central's Program on Sea Level Rise, if the high end of sea level rise predictions are realized, Miami-Dade County could be turned into a "collection of islands." Leonard Barry, Director of the Florida Center for Environmental Studies at Florida Atlantic University further explained why the Florida Keys and areas on the southeast coastline, including the City of Miami, are of special concern to climate scientists, businesses, and politicians. Firstly, Florida's flat landscape makes it particularly susceptible to flooding, and secondly, much of

[404] Chris Mooney, "Why the US East Coast Could be a Major "Hotspot" For Rising Seas," *The Washington Post*, 2016, https://www.washingtonpost.com/news/energy-environment/wp/2016/02/01/why-the-u-s-east-coast-could-be-a-major-hotspot-for-sea-level-rise.
[405] Joe Romm, "Is Climate Change Supercharging Storms Like Jonas and Sandy More Than We Thought," *Think Progress*, 2016, http://thinkprogress.org/climate/2016/01/25/3742321/climate-change-jonas-sandy/.
[406] John Upton, "Sinking Atlantic Coastline Meets Rapidly Rising Seas," *Climate Central*, 2016, http://www.climatecentral.org/news/sinking-atlantic-coastline-meets-rapidly-rising-seas-20247.
[407] Charles Q. Choi, "Sea Levels Rising Fast on US East Coast," *National Geographic*, 2012, http://news.nationalgeographic.com/news/2012/06/120625-sea-level-rise-east-coast-us-science-nature-climate-change.
[408] Montgomery, "In Norfolk, Evidence of Climate Change is on The Streets at High Tide."
[409] Erika Spanger-Siegfried, "Winter Storm Jonas, Storm Surge, and the Science of Coastal Flooding," *Union of Concerned Scientists*, 2016, http://blog.ucsusa.org/erika-spanger-siegfried/winter-storm-jonas-storm-surge-and-the-science-of-coastal-flooding.

Florida's population lives within a meter (a few feet) above sea level, and that population is growing.[410] Second, in 2012, there were 106 municipalities in which over half of residents lived on land less 1.2 meters (four feet) above sea level. Thirdly, Florida is built upon a foundation of porous limestone, rendering sea walls or levees ineffective as seawater is able to rise up into the bedrock and push the water table higher—even in more inland areas. Lastly, this same saltwater intrusion into the freshwater aquifer is a constant threat to local water supplies, a harbinger of future water insecurity in the area.[411]

If carbon emissions remain unchecked, the future of Florida's coastal communities and even many of its inland communities may become extremely bleak. The truth is that some of Florida's coastal communities may already be beyond saving and inland communities are also very vulnerable due to Florida's porous limestone. Unfortunately, even if the world's population suddenly ceased to emit greenhouse gases (GHGs) tomorrow, the Earth's radiative balance would not recover instantaneously—in fact, the existing GHGs in the atmosphere would warm the surface of the planet by an average additional 0.6 degrees over the next several decades.[412] Short of the immediate development and implementation of carbon extracting technology on a huge scale or effective geoengineering methods, parts of Florida may inevitably become unsuitable for human habitation, forcing the relocation of some of the state's population to higher ground in other regions.

Florida is already experiencing the tangible effects of climate change. The City of Miami Beach is a perfect example of an eminent U.S. city that is already being tangibly affected by a changing climate. Philip Levine, Mayor of Miami Beach and active proponent of climate change prevention and mitigation was quoted in an interview for *The Atlantic*: "I think that in every generation there's going to be a big cause; there's going to be a challenge, or a war. I think today we have sea level rise and climate change."[413] Levine believes that in the last three to seven years, flooding has "gotten worse and it's gotten faster."[414] The flooding he is primarily speaking of is called "sunny day flooding," a phenomenon directly linked to rising sea levels, and increasingly present in Miami Beach. Without any rain, city residents will find water coming up through their drains and flooding the streets. In the past, the city would have drained the water and dumped it out into the bay via outfalls. Now, with sea levels twenty centimeters (eight inches) higher than those recorded in 1870, the water level in Miami has risen past the outfalls, causing the drained water to reverse and come back up to street level.[415] These "sunny day" floods have become more frequent, disruptive, and are evidence of a problem that for many cities is distant, but is imminent for Miami Beach.

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[410] U.S. Congress, Senate, Committee on Energy and Natural Resources, *Sea Level Rise: Hearing Before the Committee on Energy and Natural Resources United States Senate*, 102 Cong., 2nd sess., 2012, https://www.gpo.gov/fdsys/pkg/CHRG-112shrg76897/pdf/CHRG-112shrg76897.pdf.
[411] Ibid.
[412] "If We Immediately Stopped Emitting Greenhouses Gases, Would Global Warming Stop?", Earth Observatory Blogs, *U.S. National Aeronautics and Space Association*, July 7, 2007, https://earthobservatory.nasa.gov/blogs/climateqa/would-gw-stop-with-greenhouse-gases/.
[413] "Is Miami Beach Doomed?" video by *The Atlantic,* February 8, 2016, http://www.theatlantic.com/video/index/460332/is-miami-beach-doomed.
[414] Ibid.
[415] Forbes Tomkins and Christina DeConcini "Sea Level Rise and Its Impact on Miami-Dade County," *World Resources Institute,* 2014, http://www.wri.org/publication/sea-level-rise-and-its-impact-miami-dade-county.

The challenges that Florida faces are glaring examples of how climate change has become a deeply politicized, partisan issue. Cities like Miami Beach and Fort Lauderdale are actively trying to fortify city infrastructure against rising sea levels, but this is made difficult by Republican governor Rick Scott and the Republican-controlled legislature in Tallahassee, who both vehemently oppose the notion of climate change.[416] In Miami, Levine's attempts to rebuild and sustain infrastructure have been blocked by Tallahassee. In his interview for *The Atlantic,* Levine lamented, "Unfortunately, we have an administration in Tallahassee that doesn't believe in sea level rise." The politicization of the climate change debate has hindered effective policy-making.

The National Oceanic and Atmospheric Administration estimates that if sea levels rise to the low-end estimate of .9 meters (approximately 3 feet) by the end of the century, 4.2 million Americans will be affected—half of whom will be Floridians.[417] With increasing numbers living in at-risk areas in the southeastern United States, particularly Florida, it is essential that policy makers recognize the problem and come to terms with the reality that rising sea levels will continue to damage infrastructure and high-valued real estate, infiltrate clean water supplies, and disrupt citizens' daily lives and livelihoods.

The following figure shows the effect of a 1.5 meter sea-level rise in southern Florida, which—although an extreme end-of-the-century estimate—could be realistic with a sudden and unexpected Antarctic ice sheet collapse.[418] The figure makes clear that the consequences of such an increase in sea level would inundate nearly all the Everglades, and many of the major areas and cities along Florida's southern coast including the Keys, Naples, Miami, and Fort Lauderdale. More conservative sea level rise estimates may not look quite like this, but with increasing storm surge and worries about future King Tides, this map still depicts the most vulnerable areas in south Florida.

[416] "Is Miami Beach Doomed?" *The Atlantic*.
[417] "Stories from the Field: Examining Sea Level Rise Exposure For Future Populations," *U.S. National Oceanic and Atmospheric Administration, Office for Coastal Management*, last modified August 21, 2017, accessed March 28, 2018, https://coast.noaa.gov/digitalcoast/stories/population-risk.html.
[418] Amanda Ruggeri, "Miami's Fight Against Rising Seas," *BBC*, April 4, 2017, http://www.bbc.com/future/story/20170403-miamis-fight-against-sea-level-rise.

Impact of 1.5-Meter Sea Level Rise on Southern Florida

Source: National Geographic

Hampton Roads, Virginia

Nowhere is the direct impact of sea level rise on American geostrategic interests more apparent than in the Hampton Roads region of southeastern Virginia, which is home to over 1.6 million people, includes the cities of Norfolk, Virginia Beach, and Newport News, and is, crucially, the location of a series of U.S. military installations that collectively comprise, "the greatest concentration of military might in the world."[419] The region is particularly important for U.S. naval operations, with the Navy's facilities there comprising the largest naval installation in the world.[420] The Navy has long centered its operations there as a result of multiple attractive geographic features—the second largest port on the U.S. East Coast only 30 kilometers (18 miles) from open ocean on one of the world's deepest naturally sheltered, ice-free harbors.[421] Military activities are also key to the region's economy: military spending is responsible for forty-six percent of local economic activity, and the military is responsible for almost 400,000 jobs in the area.[422, 423]

However, many of the same geographic features that make the region attractive for naval operations also render it vulnerable to the effects of sea level rise. Hampton Roads is subject to the highest rates of sea level rise of anywhere on the East Coast (a region already subject to disproportionately large sea level rises more generally) and is at greater risk from sea level rise than any other large population center in the United States except New Orleans.[424] Much of the population (and many military installations) is located in low-lying areas, and the topography does not pose significant obstacles to flooding incursion in most places. The figure below makes clear that many key installations are vulnerable to even a relatively modest sea level rise.

The following figure makes clear that even a one-meter sea level rise (3.28 ft.) (dark pink), which is predicted by 2100 under the RCP8.5 "business as usual" emissions scenario, would inundate major military infrastructure in the Hampton Roads region, including Langley Air Force Base, parts of the town of Hampton proper, Norfolk Naval Air Station, and Portsmouth Naval Shipyards. A 3-meter rise (9.84 ft.) (light pink), the possible result of significant storm surge, would have an even more devastating effect on the region and potentially shut down and severely damage military facilities for a protracted period.

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[419] Caitlin Werell and Francesco Femia, "New BRIEFER: Hampton Roads, Virginia and the Military's Battle Against Sea Level Rise," *Climate and Security*, 2015, https://climateandsecurity.org/2015/10/15/new-briefer-hampton-roads-virginia-and-the-militarys-battle-against-sea-level-rise.

[420] "Navy Bases: More than Just the Basics," *U.S. Naval Recruiting Command*, accessed March 8, 2018, https://www.navy.com/about/locations/bases.html.

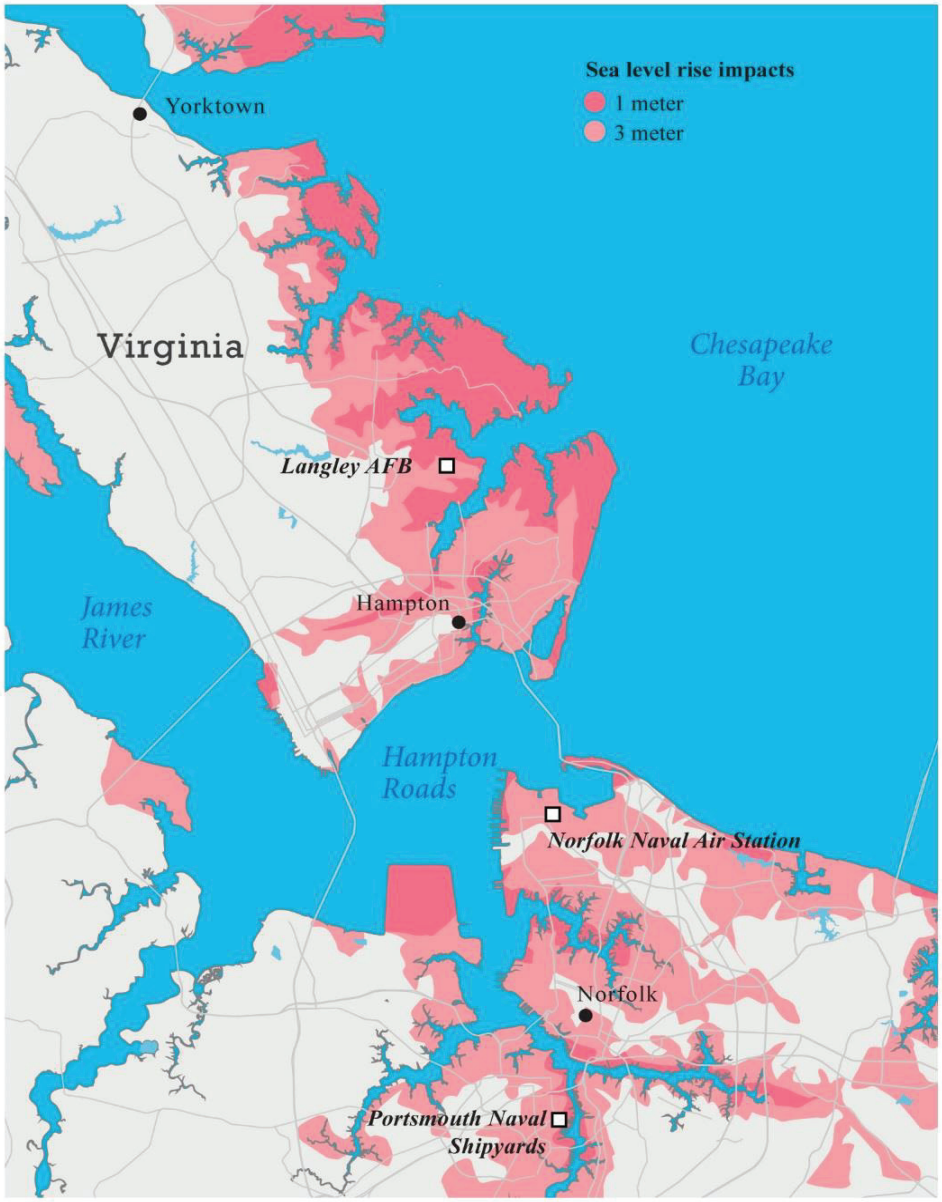
[421] "2016 Virginia Ports Annual," *Virginia Maritime Association*, 2016,

[422] Forbes Tomkins and Christina Deconcini, "Sea Level Rise and Its Impact on Virginia", *World Resources Institute*, 2014, https://www.wri.org/sites/default/files/wri_factsheet_virginia_final.pdf.

[423] U.S. State of Virginia, Hampton Roads Planning District Commission, *Economic Impact of the Department of Defense in Hampton Roads,* October 2013, http://www.hrpdcva.gov/uploads/docs/Economic%20Impact%20of%20the%20DoD%20in%20Hampton%20Roads-%20DRAFT.pdf.

[424] Tomkins, "Sea Level Rise and Its Impact on Virginia.

Hampton Roads Infrastructure: Potential Impact of One and Three Meter Sea Rise on Military Sites



Source: U.S. Environmental Protection Agency

This has major implications for military readiness as flooding is already impacting U.S. naval operations. In addition to increasing upkeep costs by millions of dollars a year, tidal flooding frequently makes facilities inaccessible and high waves negatively impact naval repairs in dry docks. By 2040, it is estimated that daily tides will render the U.S. Navy's largest installation in the region, Naval Station Norfolk (NSN), inaccessible by road for two to three hours a day without an elevated roadway.[425] Rising seas will also demand hundreds of millions of dollars in investment in adaptation strategies, such as the replacement of the main piers at NSN, at a time when military budgets have come under increasing strain. Even a relatively modest sea level rise of under half a meter (1.5 ft.)—likely by 2050 and less than half of projections for the coming century—would have significant adverse impacts on the operational efficiency and capabilities of forces stationed at NSN, in a way that could undermine U.S. naval objectives for a large portion of the fleet.[426]

A modest rise in sea level also significantly increases the risk of a major flooding event that could cripple or incapacitate military infrastructure in the Hampton Roads region, possibly degrading naval readiness for critical windows of time. Additionally, increasingly numerous and intense natural disasters, including flooding, storms, wildfires, and droughts across the country could impact readiness by placing increased demands on the National Guard, Coast Guard and other reserve forces that are relied upon in the U.S. total force concept.[427] With only a one-and-a-half-foot rise in sea level, the probability of an extreme flooding event that would cripple military infrastructure increases from 1 percent per year to over 10 percent per year.[428] Further, even if this level of risk does not force the relocation of military facilities, the over three-foot rise anticipated by 2100 is likely to render many facilities disabled due to recurrent flooding, even if they did 'dodge the bullet' of an extreme event.

It is clear that climate change has and will continue to significantly impact U.S. military operations in Hampton Roads. In particular, it is likely that naval operations (which cannot simply rebase inland) will endure the most severe impacts from rising seas. America's navy is critical to ensuring rapid force projection capabilities around the globe, and in order to retain this ability, the Navy will, in all likelihood, either have to move the heart of its Atlantic operations from the Hampton Roads area (thus abandoning the geographic and strategic benefits conferred by its harbor) or invest in a series of highly expensive levees and sea walls. Either of these options would drain significant resources from a Navy that is already struggling to meet its global commitments,[429] and by their nature, would not guarantee a solution. Sea walls are not a panacea

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[425] Sarah Volkman, "Hampton Roads: Climate Adaptation, Preparedness and Resilience Exercise," *The Center for Climate and Security*, December 15, 2014, https://climateandsecurity.org/2014/12/15/hampton-roads-climate-adaptation-preparedness-and-resilience-exercise/.

[426] "Risk Quantification for Sustaining Coastal Military Installation Assets and Mission Capabilities," *Strategic Environmental Research and Development Program,* June 2014, https://www.serdp-estcp.org/Program-Areas/Resource-Conservation-and-Climate-Change/Climate-Change/Vulnerability-and-Impact-Assessment/RC-1701.

[427] "National Security and The Accelerating Risks of Climate Change," *Center for Naval Analyses Military Advisory Board,* May 2014, https://www.cna.org/cna_files/pdf/MAB_5-8-14.pdf.

[428] Matt Conolly, "Hampton Roads Virginia and The Military's Battle Against Sea Level Rise," *The Center for Climate and Security,* 2015, https://climateandsecurity.files.wordpress.com/2015/10/hampton-roads-virginia-and-military-battle-against-sea-level-rise.pdf.

[429] Bryan McGrath, "No, The US Navy Isn't Big Enough," *War on the Rocks,* 2015, http://warontherocks.com/2015/03/no-the-navy-isnt-big-enough/.

and any alternative coastal location for a naval base will almost certainly have struggles with rising waters as well.

In addition to the direct effects on military operations, rising seas will likely impact Hampton Roads in several other ways. First, a reduction in military activity in the region would severely harm the area's economy, given the degree to which it is currently driven by military investment. More generally, businesses and homeowners are already suffering as the cost of insuring property in the region has spiraled, and likely will continue to increase considerably in the coming decades.[430] This can only have a deterrent effect on economic activity in the region and may drive businesses and residents from the region. Further, as the amount of land suitable for development and investment decreases due to inundation, economic activity is likely to be constrained. Ultimately, one meter (3.2 ft.) of sea level rise could cost the region up to $87 billion in economic activity and displace almost 190,000 residents.[431] Even today, up to one billion dollars in infrastructure investment is needed to mitigate increased flooding.[432]

The long-term economic viability of the region is under serious threat from military relocation, dwindling available land, displaced residents and businesses, and spiraling insurance costs. In similar fashion, rising seas threaten the military's ability to carry out its mission and, by extension, threaten U.S. national security interests. Hampton Roads clearly demonstrates the current and expected impacts of the most direct manifestation of climate change on both U.S. national security, and regional economic security.

The New York Metro Area

The New York metropolitan area, similarly situated along the rising seas 'hotspot' of the Atlantic coast, is subject to many of the same human security challenges discussed above in reference to southeastern Virginia—only on a massively amplified scale. New York City is rendered particularly vulnerable by its island location and low lying topographical profile, but the risks to human security in the area are enhanced by the city's dense population, aging infrastructure, and economic importance.

The New York area can expect similar rises in sea level to those Hampton Roads will experience in the coming century—a potential increase of over 1.2 meters (four ft.).[433] Such rises present similar risks: inundating waterfront properties and posing increased risk of flooding from storm surges (the severity of which will be compounded by the effects of climate change).

Given the high value of land and abundance of economic activity in the New York area, the potential costs of inundation and increased flooding are immense, as demonstrated by the costs of Hurricane Sandy in 2012, which were estimated at over $65 billion.[434] As climate change

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[430] Sarah Kleiner, "Getting Insurance Along the Coast is Getting Pricey," *The Virginian-Pilot,* 2013, http://pilotonline.com/business/getting-insurance-along-the-coast-is-getting-pricey/article_ed841c28-75e2-5679-a56e-3e085d46ee0a.html.
[431] Tomkins, "Sea Level Rise and Its Impact on Virginia."
[432] Ibid.
[433] "Sea Level Rise," *New York State Department of Environmental Conservation,* http://www.dec.ny.gov/energy/45202.html.
[434] Doyle Rice and Alia E. Dastagir, "One Year After Sandy, 9 Devastating Facts," *USA Today*, October 29, 2013, http://www.usatoday.com/story/news/nation/2013/10/29/sandy-anniversary-facts-devastation/3305985.

continues to affect sea levels and weather patterns, this type of damage will become increasingly common, especially if one also considers the potential damage to New York City's $41 billion tourism industry. One estimate placed the value of land at risk of inundation at roughly $170 billion over the next century, where nearly one million people live. Just as in Virginia, the potential loss of valuable land is accompanied by the compounded issues of rising insurance premiums.[435]

New York City's vulnerability to higher sea levels is compounded by its dependence on large quantities of aging infrastructure. The city is home to hundreds of miles of aging subway tracks and decaying water mains, as well as almost fifty bridges deemed in "critical condition."[436] In the dense, heavily interconnected environment of New York City, infrastructure failures could cause massive disruption and enormously multiply the costs of flood damage. Flooded subways could be ruined, depriving access to public transportation for millions of pedestrians. Storms could wreck bridges, severing the links between the city's heavily populated islands, or sewer pipes could burst, causing a public health crisis.

The New York area, then, represents a clear example of the threats to economic security posed by rising seas. It is in the long-term interest of the United States to seek ways to mitigate the potentially catastrophic effects of rising sea levels. The preservation of national economic stability, critical infrastructure, and the lives and livelihoods of millions in vulnerable areas of New York City depend on effective American leadership in addressing the issue.

Louisiana: Isle de Jean Charles and America's First Climate Refugees

The very nature of the climate change debate is plagued with "what-ifs" and hypothetical situations, which inevitably limit effective policymaking and preventative action. However, for the residents of Isle de Jean Charles, a narrow island off the coast of the Terrebonne Parish in southern Louisiana, climate change does not pose a distant threat, but rather an imminent one. The residents, many of whom belong to the Biloxi-Chitimacha-Choctaw tribe, are being hailed as the first American "climate refugees," as their impending migration to the Louisiana mainland is undoubtedly the result of climate change. Sea levels are rising and the Isle is sinking simultaneously; it has seen a 98 percent loss of land since 1955, and the United States Department of Housing and Urban Development (HUD) has awarded the town $48 million in National Development and Reform Commission (NDRC) funding "to relocate to a resilient and historically-contextual community."[437]

The Isle de Jean Charles website best sums up the challenges the people of this narrow strip of land are facing: "coastal erosion and saltwater intrusion, caused by canals dredged through our surrounding marshland by oil and gas companies, land sinking due to a lack of soil renewal…and rising seas."[438] What was once an island of 22,000 acres just 60 years ago is now a

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[435] "The Rising Cost of Floor Insurance in New York City," *Rand Corporation,* 2016, http://www.rand.org/pubs/research_briefs/RB9745.html.
[436] Adam Forman, "Caution Ahead: Overdue Investments for New York's Aging Infrastructure," *Center for an Urban Future,* March 2014, https://nycfuture.org/research/publications/caution-ahead.
[437] George I. Gonzalez, "HUD Awards $1 Billion Through National Disaster Resilience Competition*, US Department of Housing and Urban Development,* January 21, 2016, https://archives.hud.gov/news/2016/pr16-006.cfm.
[438] "Our History" *Isle De Jean Charles, Louisiana*, accessed March 8, 2018, http://www.isledejeancharles.com/.

meager 320 acres, and scientists predict that the island will be inundated within 50 years.[439] There is only one bridge that connects the Isle to the mainland, and it is often flooded, leaving residents unable to commute to Louisiana's terra firma for work, school, or doctor's appointments.[440] All aspects of the residents' livelihood have been threatened by climate change: saltwater intrusion into inlets and wetlands due to canal dredging has inhibited the tribe's ability to grow produce, encroaching sea levels and flooding have diminished the available land for cattle grazing, and homes have become additionally threatened with each flood.[441]

The Isle is home to the Biloxi-Chitimacha-Choctaw tribe, a French-speaking native population that has lived on the island since the late-1800s. Many of the current residents can trace their ancestry back to the four original families that first settled in what was once thought to be "uninhabitable swamp land."[442] The small island is one of the only communities in the area to have maintained a chiefdom from historic settlement to present day. Although there is a strong sense of community and dedication to the land that once provided all the means necessary for a fruitful existence, some residents have come to terms with the fact that climate change has rendered their homeland unsustainable. As eighty-two-year-old resident Joann Bourg told the *New York Times*, "Yes, this is our grandpa's land, but it's going under one way or another."[443]

In January of 2016, the HUD awarded $1 billion to "13 states/communities to receive funding for resilient infrastructure and housing projects."[444] Louisiana will receive approximately $92 million for the Louisiana Strategic Adaptations for Future Environments Program (LA SAFE), with over half of the sum going to Isle de Jean Charles specifically. The funding dedicated to the small island is unprecedented in that the fund's purpose is not to fortify levees, build sea walls, or raise roads—it is to physically relocate an entire community to drier land that will stand the test of rising sea levels and storm surges. Walter Kaelin of the Nansen Initiative, a research organization dedicated to mitigating the effects of extreme-weather and climate change displacement, encapsulates the reasoning behind the HUD's desire to relocate the Isle de Jean Charles community: "You don't want to wait until people have lost their homes, until they flee and become refugees," he said. "The idea is to plan ahead and provide people with some measure of choice."[445] However, moving an entire community with a deep connection to the land they live on to a "historically contextual and culturally appropriate resettlement" area is a tall order. HUD hopes to make the relocation of the Biloxi-Chitimacha-Choctaw tribe a national model. The Lowlander Center, a non-profit organization supporting lowland people of Louisiana, has high expectations for the federal government to deliver; "buildings will be energy-efficient and protected from storm

[439] Holly Duchmann, "Sense of Urgency Surrounds Isle de Jean Charles Relocation," *Houma Today*, January 7 2016, http://www.houmatoday.com/article/20160125/ARTICLES/160129832?p=2&tc=pg.
[440] Coral Davenport and Campbell Robertson, "Resettling the First American Climate Refugees," *The New York Times,* May 3, 2016, http://www.nytimes.com/2016/05/03/us/resettling-the-first-american-climate-refugees.html?_r=0
[441] "The Environment," *Isle De Jean Charles, Louisiana*, accessed March 8, 2018 http://www.isledejeancharles.com/the-environment/.
[442] "Our History," *Isle De Jean Charles*.
[443] Davenport, "Resettling the First American Climate Refugees."
[444] Gonzalez, "HUD Awards $1 Billion."
[445] Davenport, "Resettling the First American Climate Refugees."

damage, land use will be sustainable and productive, and a close-knit and self-supporting community will encourage positive relations and economic development."[446]

In the last 100 years, Louisiana has lost of 4,920 square kilometers (1,900 square miles) of land.[447] The state's plans to fortify the coast do not apply to seemingly lost causes like Isle de Jean Charles, an island once 17 kilometers (11 miles) long and eight kilometers (five miles) wide, now less than 3.2 kilometers (two miles) long and a 0.4 kilometers (a quarter-mile) wide.[448] Officials from HUD understand that they could devote their funds to rebuilding the island as it was before, but with a plethora of climate change data projecting a bleak future, it would neither be cost-effective nor prudent to act as though the Isle could survive another 100 years. The best option is to physically relocate the residents, and despite some support among residents for the move, many have vowed to stay on the island where they were raised, their parents are buried, and their children were born.[449]

Isle de Jean Charles provides insight into one small community's struggle with a changing climate, but it also serves as a microcosm of what could be the fate of many coastal communities in the United States. As Mark Davis, director of the Tulane Institute on Water Resources Law and Policy, said to the *New York Times*, "If you have a hard time moving dozens of people," he continued, "it becomes impossible in any kind of organized or fair way to move thousands, or hundreds of thousands, or, if you look at the forecast for South Florida, maybe even millions."[450] There are only 27 families left on Isle de Jean Charles, and animosity among community members about whether to stay or leave already exists; a relocation for the entire population of the City of Miami Beach would be exponentially more difficult.

The southeast United States is especially vulnerable to the effects of sea level rise, extreme weather events such as hurricanes and heat waves, and decreased water availability. Atlanta and Miami are two of the most populous cities in the country, and in 2012 alone, Florida and Louisiana hosted more than 115 million visitors.[451] The consequences of migrations akin to what is expected of the Isle de Jean Charles residents on the southeastern tourism, seafood, agriculture, military, oil, and gas industries would be staggering. Just as the Biloxi-Chitimacha-Choctaw tribe finds itself in a difficult situation, so too would the millions of citizens of the Louisiana mainland whose homes might be put at risk by climate change. The Department of Housing and Urban Development has set aside $48 million for the relocation of America's first climate refugees. If the population of New Orleans ever had to be relocated, the HUD would have to allocate far more than that.

The following figure shows the effect of a 1 meter (3.28ft) rise in sea level along the Louisiana coast, as predicted by 2100 (shown in red) by the IPCC's RCP8.5 high-end scenario.

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[446] "About the Project," *Lowlander Center*, accessed March 28, 2018, http://www.coastalresettlement.org/about-the-project.html.
[447] Saskia de Melker, "Coping with Climate Change: Louisiana's Vanishing Coast," *Public Broadcasting Service,* June 1, 2012, https://www.pbs.org/newshour/science/multimedia-louisianacoast.
[448] Ibid.
[449] Davenport, "Resettling the First American Climate Refugees."
[450] Ibid.
[451] Lynne M. Carter and James W. Jones, et al., "2014 National Climate Assessment: Southeast and the Caribbean," *U.S. Global Change Research Program*, May 2014, http://s3.amazonaws.com/nca2014/low/NCA3_Climate_Change_Impacts_in_the_United%20States_LowRes.pdf?download=1.

The increase in sea level would inundate much of southern Louisiana, including New Orleans, Houma, Slidell, and southern parts of Lafayette, Lake Charles, Hammond, and the southern outskirts of the Baton Rouge suburbs.

Source: Weiss and Overpeck, University of Arizona

Chapter 12: The Hurricane Season of 2017

Introduction

Attributing a single extreme weather event climate change is notoriously difficult even with modern technology and models. However, there are clear correlations between climate change and numerous major variables influencing the severity, frequency, and probability of occurrence of natural disasters—allowing scientists to conclude that several of these events may worsen in the future. Atlantic-basin hurricanes (elsewhere referred to as "tropical cyclones" or "typhoons") affecting the United States and its territories are expected to become more severe, with greater rainfall and higher wind speed as global warming continues.[452] The United States has large hurricane-prone coastlines, making this a substantial threat to safety, infrastructure, livelihoods, and local and regional economies—and to U.S. security.

In a literature review by NOAA's Geophysical Fluid Dynamics Laboratory, authors concluded that, "it is likely that climate warming will cause Atlantic hurricanes in the coming century to have higher rainfall rates than present-day hurricanes, and [there is] medium confidence that they will be more intense (higher peak winds and lower central pressures) on average."[453] Global warming is expected to increase global evaporation rates as a result of rising atmospheric and sea surface temperatures. Hotter surface temperatures allow for greater rates of evaporation, and as this water vapor is forced to rise, it eventually condenses in cooler reaches of the atmosphere and releases what is known as "latent heat." Latent heat is the primary source of fuel for hurricanes, allowing them to self-propagate and intensify along a track of warm waters. Atmospheric water vapor content also increases with increasing evaporation rates and is related to higher precipitation rates within the storm itself—a marker of a more intense, more damaging storm.

The strongest connection between climate change and hurricane destructiveness, however, is the manner in which higher sea levels allow for greater storm surges. Storm surge, by general definition, refers to abnormally high coastal water levels generated by severe storms. A surge

[452] "Global Warming and Hurricanes: An Overview of Current Research Results," *U.S. National Oceanic and Atmospheric Administration*, last modified January 24, 2018, accessed March 30, 2018, https://www.gfdl.noaa.gov/global-warming-and-hurricanes/.
[453] Ibid.

occurs when "strong winds over the ocean combine with low atmospheric pressure to drive water onshore," producing abnormally high sea levels and causing "extreme coastal and inland flooding."[454] Experts at the U.S. NOAA have contended that as a result of global sea level rise, modern storm surges are twenty centimeters (eight inches) higher than they would have been in 1900. The predicted additional 0.3 to 2 meter (approximately one to six and a half feet) of sea level rise by the end of the century will come atop of this, making hurricanes an even larger and looming threat to coastal U.S. cities."[455]

Hurricane Harvey

On August 25, 2017, Hurricane Harvey made landfall as a category 4 hurricane with 130 mph sustained winds, near the town of Rockport, Texas. For the next five days, Harvey battered southeastern Texas and southwestern Louisiana before moving over Tennessee and Kentucky.[456] The storm dropped an estimated 33 trillion gallons of rainfall on the United States,[457] flooded 50 counties across Texas, and set a new U.S. rainfall record of 153.87 centimeters (60.58 inches) near Nederland Texas.[458] NOAA estimates the cost of this "1,000 year flood," at about $125 billion—the second costliest hurricane disaster on record for the United States after Hurricane Katrina in 2005.[459]

In its wake, 68 people died, over 300,000 structures were damaged, some 40,000 people were evacuated to shelters, and around 500,000 cars were destroyed.[460] Researchers from Texas A&M's AgriLife Extension Service put agricultural loses at more than $200 million, with livestock and crop losses extensive across all the affected areas.[461] Parts of Houston and southeastern Texas remain in need of significant assistance as local industries, private property, and infrastructure have suffered significant damage.

Some climate scientists believe that anthropogenic climate change played an important role in creating the conditions that strengthened Hurricane Harvey, particularly by increasing water temperatures in the Gulf of Mexico. Climate data indicates that Hurricane Harvey was "fueled by

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[454] "Storm Surge," U.S. Climate Resilience Toolkit, Climate Program Office, *U.S. National Oceanic and Atmospheric Administration*, last modified October 6, 2017, accessed March 6, 2017, https://toolkit.climate.gov/topics/coastal/storm-surge.
[455] Ibid.
[456] Leanna Garfield, Sky Gould, and Rebecca Harrington, "Hurricane Harvey is the Worst Rainfall Disaster in U.S. History – This Interactive Map Shows How Bad It Was," *Business Insider*, August 31, 2017, http://www.businessinsider.com/hurricane-harvey-2017-rainfall-map-2017-8.
[457] Angela Fritz and Jason Samenow, "Harvey Unloaded 33 Trillion Gallons of Water in the U.S.," *The Washington Post*, September 2, 2017, https://www.washingtonpost.com/news/capital-weather-gang/wp/2017/08/30/harvey-has-unloaded-24-5-trillion-gallons-of-water-on-texas-and-louisiana/?utm_term=.3f9db71d1dd8.[458] Eric S. Blake and David A. Zelinsky, "Tropical Cyclone Report: Hurricane Harvey," *U.S. National Hurricane Center*, January 23, 2018, https://www.nhc.noaa.gov/data/tcr/AL092017_Harvey.pdf.
[458] Eric S. Blake and David A. Zelinsky, "Tropical Cyclone Report: Hurricane Harvey," *U.S. National Hurricane Center*, January 23, 2018, https://www.nhc.noaa.gov/data/tcr/AL092017_Harvey.pdf.
[459] Fast Facts: Hurricane Costs, *National Oceanic* and *Atmospheric Administration*, *Office for Coastal Management*, January 18, 2018, https://coast.noaa.gov/states/fast-facts/hurricane-costs.html.
[460] Blake and Zelinsky, "Tropical Cyclone Report: Hurricane Harvey."
[461] Balir Fannin, "Texas Agricultural Losses from Hurricane Harvey Estimated at More Than $200 Million," *AgriLife TODAY*, October 27, 2017, https://today.agrilife.org/2017/10/27/texas-agricultural-losses-hurricane-harvey-estimated-200-million/.

waters that [were] nearly 1 degree Celsius warmer than in the past."[462] Climate scientists estimate that the higher-than-average temperature of the Gulf increased total storm moisture by between 3 to 7 percent, and that the increase in moisture had a substantial effect on the rainfall and flooding that took place.[463] According to data provided by Texas State University climatologist John Nielsen-Gammon, Hurricane Harvey produced the largest rainfall of any US hurricane on record.[464]

However, the record-breaking rainfall across southeastern Texas was not just due to the increased moisture content of the storm, but due to the storm's very slow pace. Hurricane Harvey "stalled" over the region for multiple days "due to very weak prevailing winds which…fail[ed] to steer the storm off to sea [or further inland and westward]," as would typically take place.[465] Michael Mann, a professor of atmospheric science at Penn State University, has observed that this pattern—which was "predicted by computer simulations of human-caused climate change"—was due to a "greatly expanded subtropical high-pressure system over much of the U.S…with the jet stream pushed well to the north." Yet, due to the numerous factors involved, it is nearly impossible to prove that climate change caused Hurricane Harvey's "stalling" over the region.[466]

Nonetheless, Kerry Emanuel, professor of atmospheric science at MIT, points out that the "sudden 'collapse' of the speed of currents in the Gulf of Mexico" is extremely unusual and requires additional research to explain. Gulf currents averaged around 19 knots until the end of 2010, but dropped below 14 knots on average in 2016.[467] While the decrease in Gulf current speeds played a significant role in increasing the probability of slow-moving storms in the region, there still isn't enough long-term data to directly connect climate change to reduction in Gulf currents. Ultimately, there is still no consensus among climate scientists as to the cause of slower storms in the Gulf region and it may take years to understand such peculiar changes in regional currents. However, what is clear is that climate change has been playing a significant and growing role in the intensity and rate of occurrence of hurricanes and other powerful storm systems throughout the region. The growth in the average precipitation content of storms today is "linked to higher rates of evaporation that come along with higher temperatures in the atmosphere," which is directly linked to climate change.[468] The increasing likelihood of flooding events similar to Hurricane Harvey emphasizes the need for new adaptation strategies to address the threat posed by climate change, especially in the most vulnerable regions.

Researchers increasingly attribute some of Harvey's unusually severe flooding to laissez-faire zoning laws and urban development policies in the City of Houston and Harris County. Harris County, and, within it, the City of Houston have historically resisted instituting more stringent

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[462] James Rainey, "Blame Climate Change for Packing Harvey with Rain, but Not for its Slow Pace," *NBC News*, August 29, 2017, https://www.nbcnews.com/news/weather/blame-climate-change-harvey-s-huge-rainfall-not-its-slow-n797151.
[463] Ibid.
[464] Kerry Emanuel, "Assessing the Present and Future Probability of Hurricane Harvey's Rainfall," *Proceedings of the National Academy of Sciences of the United States of America* 114, no. 48 (2017): 12681-12684.
[465] James Rainey, "Blame Climate Change for Packing Harvey with Rain, but Not for Its Slow Pace," *NBC News*, August 29, 2017, https://www.nbcnews.com/news/weather/blame-climate-change-harvey-s-huge-rainfall-not-its-slow-n797151.
[466] Ibid.
[467] Ibid.
[468] Ibid.

building codes. Houston has experienced an unprecedented level of development over the last few decades: in the city of Houston, the population increased 25 percent from 1995 to 2015, reaching 2.2 million, and in Harris County the population grew 42 percent to 4.4 million.[469] Much of that development has been "virtually unchecked, including in flood-prone areas [which] has diminished the land's already-limited natural ability to absorb water." On top of that, "the city's drainage system [which is made up of] a network of reservoirs, bayous, and, as a last resort, roads that hold and drain water [was never] designed to handle the massive storms that are increasingly common."[470] Making matters worse, Harris County's 34 municipalities have been allowed to develop independent flood management procedures and regulations with little to no consideration of their effects on other parts of the county. In the past, flood control projects consistently failed to gain enough support, and on multiple occasions residents rejected new zoning codes that could reduce flooding and improve resiliency to flooding.[471] These initiatives have only recently begun to gain support and both the city and county have pushed stricter zoning regulations since the floods subsided. Nevertheless, funding for improvement projects has been slow in arriving.[472]

Despite the growing risk from flooding, Houston has consistently prioritized economic development above all other considerations and has made every effort to avoid restrictions that might hurt economic development. Houston has been willing to pursue modest engineering solutions, but little else. These engineering solutions consist of a combination of bayous, streams, and channels that act as the main drainage system while streets and detention ponds handle overflow. However, the city was "built on a low-lying coastal plain…clay-based soil that is [one of] the least absorbent in the nation"[473]—something that further exacerbates flooding. To make matters worse, "since 2010, at least 7,000 residential buildings [were] constructed in Harris County on properties that sit mostly on land the federal government has designated as a 100-year flood plain."[474]

In light of Houston's topographical disadvantage and high degree of vulnerability to flooding, new development polices and more substantial engineering solutions are needed to improve the city's resilience to future storms. While no regulation or improved drainage system could have saved Houston from the unprecedented effects of Harvey, improvements in zoning and development regulations, as well as higher capacity drainage infrastructure, could have reduced some of the most severe effects of the storm and reduced the amount of people and property put in harm's way.[475] Moreover, modest solutions are no longer sufficient in light of stronger storms and increased flooding due to climate change. Moving forward, no construction should take place in flood prone areas and new buildings should be elevated to minimize the risks floods pose to them.[476]

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[469] Shawn Boburg and Beth Reinhard, "Houston's 'Wild West' Growth," *The Washington Post*, August, 29, 2017, https://www.washingtonpost.com/graphics/2017/investigations/harvey-urban-planning/?utm_term=.4483697a4201.
[470] Ibid.
[471] Ibid.
[472] Travis Bubenik, "Six Months After Harvey, Plans for a More Flood-Resilient Houston Have a Long Way to Go," *Houston Public Media*, February 26, 2018, https://www.houstonpublicmedia.org/articles/news/energy-environment/2018/02/26/269840/six-months-after-harvey-plans-for-a-more-flood-resilient-houston-have-a-long-way-to-go/.
[473] Boburg, "Houston's 'Wild West' Growth."
[474] Ibid.
[475] Ibid.
[476] Ibid.

And while the level of devastation brought by Harvey was severe, this is not the first time Houston has experienced significant flooding. Previous major flooding events in the region have caused significant damage to the Houston area. Harvey is actually the third "500 year" or greater storm to hit the Houston area in the last three years: in May 2015 and April 2016, the city was inundated by storms that dropped more than a foot of rain and caused significant property damage and loss of life.[477] Clearly these tragic events are becoming increasingly common and inaction may no longer be acceptable to either locals in the area that are suffering, or to the country's taxpayers who keep getting stuck with the bill. The city of Houston and Harris County's intransigence on the issue has turned a local problem into a pressing national issue.

Lax local policies risk not only major regional industries, such as oil facilities that are of vital national interest, but also result in huge federal payouts to finance rebuilding efforts According to federal data, "Harris County has received about $3 billion from the Federal Emergency Management Agency for losses in the past four decades," which "ranks [it] third in the amount paid by the National Flood Insurance program."[478] If the state of Texas, Harris County, and the city of Houston are unwilling or unable to act to reduce the severity of future flooding events in the region, then the federal government may have no choice but to use its authority to initiate needed reforms. If action by the federal government is required, it should pursue policies that incentivize more resilient and sustainable development and discourage the development of structures that are prone to flooding and are located in more vulnerable locations. Such polices would not only have the benefit of improving building standards, reducing development in flood-prone areas, and increasing drainage and rain-capturing infrastructure, but would also help the local economy resist weather induced disruption, and reduce the long term cost to federal tax payers.

Despite the Trump Administration's initial reluctance to get involved in local development regulations, Hurricane Harvey may have changed the administration's calculus and forced action. In early August 2017, President Trump eliminated Obama-era rules that attempted to reduce flood risks to vulnerable regions by establishing "new construction standards for roads, housing and other infrastructure projects that receive federal dollars." Trump initially "derided these restrictions…as useless red tape holding back the economy," but, in the wake of the massive destruction caused by Hurricane Harvey, his administration is now re-considering "whether to issue similar requirements to build higher in flood-prone areas as the government prepares to spend billions of dollars in response to the storm." If the Trump administration agrees to enforce Obama-era regulations it would "represent a striking acknowledgement by an administration skeptical of climate change that the government must factor changing weather into some of its major infrastructure policies."[479] Ensuring that federal assistance isn't squandered in the future may require some "encroachment" on state and local authority through federal regulations on building and zoning laws. If local officials are unwilling to take the necessary steps to protect their

[477] Christopher Ingraham, "Houston is Experiencing its Third '500-Year' Flood in 3 years. How is That Possible?" *The Washington Post*, August 29, 2017, https://www.washingtonpost.com/news/wonk/wp/2017/08/29/houston-is-experiencing-its-third-500-year-flood-in-3-years-how-is-that-possible/?utm_term=.97433c8dac18.
[478] Ibid.
[479] Juliet Eilperin, "After Harvey, the Trump Administration Reconsiders Flood Rules It Just Rolled Back," *The Washington Post*, September 1, 2017, https://www.washingtonpost.com/politics/after-harvey-the-trump-administration-reconsiders-flood-rules-it-just-rolled-back/2017/09/01/c3a051ea-8e56-11e7-8df5-c2e5cf46c1e2_story.html?utm_term=.74e40cce875d.

communities from further disasters, then it becomes the responsibility of the federal government to avoid the "moral hazard" of endless disaster fund payouts by instituting requirements for further disaster assistance.

This catastrophe provides important lessons for some of the most vulnerable cities to hurricanes in the United States, and especially those experiencing significant growth in urban development. According to Andrew Freedman at Climate Central, cities such as Tampa/St. Petersburg, Miami, New Orleans, and Norfolk/Virginia Beach are just as vulnerable to hurricanes as Houston, if not more so. All of these cities have already experienced relatively high storm frequencies, are built on low lying terrain that is vulnerable to both flooding and storm surge, and are likely to experience significant effects from both sea level rise and greater storm strength and frequency due to climate change.[480]

While no city could have handled the amount of precipitation that Houston received from Hurricane Harvey without substantial flooding, there are some preventative measures that can make a substantial difference. Glenn MacGillivray, managing director of the Toronto-based Institute for Catastrophic Loss Reduction, has argued that "good urban planning is ultimately the best way to avoid [the worst effects of] flooding caused by heavy rainfall." According to MacGillivray, "many cities fall prey to the financial lure of allowing urban sprawl, which often leads to wetlands and green spaces being paved over in the name of growth… [even though] those natural spaces are vital for absorbing heavy rainfall, and their absences can leave cities [extremely] vulnerable." MacGillivray recommends that cities "focus on building denser housing and better infrastructure [that is both stronger and better able to absorb precipitation], rather than spreading out in natural spaces."[481] Ultimately, cities that are vulnerable to flooding, and especially those experiencing significant growth, need to take a long-term view if they want to withstand the effects of stronger and more prevalent storms that are likely to develop due to climate change.

However, even if all necessary steps are taken, there is no assurance that the most vulnerable cities and regions will be able to avoid the worst effects of climate change. Without significant investments in adaptation infrastructure, such as levies, reservoirs, sea walls, improved drainage systems, the development of flood plains, relocation from the most vulnerable areas, stricter zoning and building codes, and systems that work with and improve upon the capacity of the region's natural drainage and storm surge mechanisms, some cities may be become uninhabitable and may eventually have to be relocated or abandoned.

Nonetheless, Hurricane Harvey's effects are already coming into focus. Houston and Harris County have started to re-examine their zoning laws, drainage infrastructure, and building regulations in parallel to the Trump administration's reevaluation of its policies on building regulations for regions that receive federal flood assistance. This tragedy has also provided several key lessons for U.S. cities which are vulnerable to climate change: meticulous urban planning that prioritizes sustainability, reduces land-intensive development, and accepts higher short-term costs for longer-term gains; stronger and more absorbent infrastructure; and the need for significant

[480] Andrew Freedman, "The 5 Most Vulnerable U.S. Cities to Hurricanes," *Climate Central*, June 6, 2013, http://www.climatecentral.org/news/top-5-most-vulnerable-us-cities-to-hurricanes.
[481] "Amid Harvey Floods, What are the Lessons to be Learned?" *CTV News*, August 29, 2017, http://www.ctvnews.ca/sci-tech/amid-harvey-floods-what-are-the-lessons-to-be-learned-1.3566629.

investment in drainage and water management systems. While the best course of action is to mitigate climate change in order to preempt serious weather disasters like Harvey, there may be a silver lining to this tragedy. Catastrophic events like Harvey may provide the needed motivation and essential lessons that will lead our nation and our world towards practical adaptations that can protect our most vulnerable regions before it's too late.

Hurricane Irma and the Implications of the 2017 Hurricane Season

Over ten days, from September 2 to September 11, 2017, Hurricane Irma caused tremendous damage and broke meteorological records across the Caribbean and the southeastern United States. With a maximum wind speed of 185 mph sustained for 37 hours, Hurricane Irma was the longest lasting cyclone of that intensity anywhere in the world.[482] In addition, Irma "generated the most accumulated energy of any tropical cyclone in the Atlantic tropics on record." The storm was so powerful that "the total wind energy generated over [the] storm's lifetime [reached] the National Oceanic and Atmospheric Administration's definition of an average full Atlantic hurricane season.," According to Phil Klotzbach, an atmospheric scientist at the University of Colorado who specializes in Atlantic hurricanes, Irma "was more powerful than 18 of the 51 full hurricane seasons since 1966."[483] Hurricanes that develop over the Atlantic, like Irma, are typically less intense than those that form in the warmer waters of the Caribbean. Yet climate scientists argue that the warming oceans have significantly increased the strength of the storms that originate in the Atlantic, suggesting that this problem will worsen as climate changes contributes to rising ocean temperatures.[484]

The record-breaking storm caused widespread damage across the small Caribbean island of Barbuda and much of the southeastern U.S. Moody's Analytics estimates that damage to privately insured property in the U.S. alone is between $64 and $92 billion, while the risk modeling firm AIR Worldwide assessed that "insurance losses are projected to reach as high as $40 billion."[485] These numbers seem impressive, but the impact on the United States from Hurricane Irma could have been far worse if the storm's trajectory had avoided the Cuban coast and continued on its originally predicted course across the entire eastern coast of Florida. Despite the change of direction, the storm was officially blamed for 64 deaths. Unofficial estimates have placed the death toll at over 1,000 in Puerto Rico alone.[486] Early warnings of meteorologists and widespread preparations by governments and civilians prevented the death toll from being much higher, but property and infrastructure damage was still extremely high, especially across much of the Caribbean; Anguilla, Antigua, Barbuda, the United States and British Virgin Islands, Saint Martin, and Sint Maarten saw some of the most catastrophic damage from Irma. On many of these islands, almost all electrical and water infrastructure was decimated and nearly "90 percent of all vehicles

[482] "Impacts of Irma – September 2017," *NOAA National Weather Service*, September 12, 2017, https://www.weather.gov/bmx/event_irma2017.
[483] Alex Johnson, "Hurricane Irma Winds Down, Leaving a Trail of Destruction and Broken Records," *NBC News*, September 12, 2017, https://www.nbcnews.com/storyline/hurricane-irma/hurricane-irma-winds-down-leaving-fearful-legacy-behind-n800536.
[484] Christopher Joyce, "Hurricanes are Sweeping the Atlantic. What's the Role of Climate Change?" *NPR*, September 8, 2017, https://www.npr.org/sections/thetwo-way/2017/09/08/549280066/hurricanes-are-sweeping-the-atlantic-whats-the-role-of-climate-change.
[485] Johnson, "Hurricane Irma Winds Down."
[486] Frances Robles et al., "Official Toll in Puerto Rico: 64. Actual Deaths May Be 1,052." *The New York Times*, December 9, 2017, https://www.nytimes.com/interactive/2017/12/08/us/puerto-rico-hurricane-maria-death-toll.html.

and buildings had been severely damaged or destroyed," leading to an extensive humanitarian disaster unprecedented in the history of the Caribbean.[487]

The fear of such disastrous impact in Florida led to one of the largest evacuations in U.S. history, resulting in widespread fuel shortages across the entire Floridian peninsula. Florida was extremely fortunate that Irma stalled over Cuba's northern coast before weakening to a category 4 storm with 130 mph sustained winds and changing course towards the less populous western coast. Irma later made landfall in the Keys, and then moved to the mainland just south of Naples. Despite Florida's good fortune, Irma's winds pummeled the southeastern United States. Nearly all of Florida suffered minor to moderate damage from hurricane force winds as many southeast cities experienced major damage from winds and storm surge, including Naples and Jacksonville, Florida, and Charleston, South Carolina. The storm decimated Florida's agriculture industry, with nearly 70 percent of the state's citrus crop believed to be ruined and major damage to sugar cane and vegetable crops.[488] As a result, commodity markets braced for a short-term spike in food prices nationwide and over 7 million people lost power across the southeast United States—residents in many areas spent days suffering through high temperatures without air-conditioning.[489] Trump administration officials have said that the massive loss of electricity led to "the largest-ever mobilization of [electric] line restoration workers in [United States history]."[490] In the Florida Keys, FEMA estimated that 25 percent of homes were destroyed, 65 percent of homes suffered significant damage, and the public faced a shortage of water, food, and electricity. In response, 10,000 National Guard members from across the country were deployed to the region to help with recovery efforts. [491]

Beyond the devastation brought by Hurricane Irma, or Harvey shortly before it, is the noteworthy historical nature of the 2017 hurricane season. The 2017 hurricane season was so unprecedented because "the first time on record the Atlantic had two storms with sustained speeds of over 150 mph happening at once."[492] 2017 was also the first year the United States ever experienced two landfalls by major hurricanes at Category 4 strength or above. The 2017 hurricane season not only saw unusually powerful storms but more of them as well: an average hurricane season in the Atlantic Basin sees about six named storms by September 7, but in 2017 there had been 11.[493] The 2017 hurricane season is a stark reminder that hurricanes could be a growing threat to the United States in the face of climate change and that inaction in mitigating anthropogenic forcing could contribute to a future of similar seasons.

Two key factors played an essential role in creating an extremely active and dangerous hurricane season in the Atlantic during 2017. Klotzbach observed that 2017 was a "super active"

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[487] Johnson, "Hurricane Irma Winds Down."
[488] "Hurricane Irma Death Toll at 61; Florida Power Outage at 6.8 Million People," *CBS News*, September 14, 2017, https://www.cbsnews.com/news/huricane-irma-death-toll-florida-power-outage/.
[489] Johnson, "Hurricane Irma Winds Down."
[490] Ibid.
[491] Kristen M. Clark, "After Irma Comes Recovery, and the State is Gearing Up," *Tampa Bay Times*, September 10, 2017, http://www.tampabay.com/florida-politics/buzz/2017/09/10/after-irma-comes-recovery-and-the-state-is-gearing-up/.
[492] Kevin Loria, "This is the First Time the Atlantic Has Had Two Hurricanes with 150-mph Winds at the Same Time-Here's Why This Season is so Active," *Business Insider*, September 8, 2017, http://www.businessinsider.com/hurricane-irma-effect-on-hurricane-season-2017-9.
[493] Ibid.

season, where "the lack of an El Niño cycle and abnormally warm sea temperatures and ocean heat content" contributed towards storm formation.[494] Without either the El Niño or La Niña systems (ENSO) in the Pacific, there was much less wind shear in the Atlantic, which tends to break up hurricanes despite otherwise favorable meteorological conditions. Moreover, the Atlantic's water temperatures, in terms of both "ocean heat content, a measure of heat stored by the ocean; and sea surface temperatures, measure at the top layer of the ocean" were higher than normal.[495] Climate scientists have suggested that "weaker trade winds and wind speeds in the Atlantic have led to less evaporation, which would normally cool the ocean more."[496] Other possibilities are that changing pressure systems forced surface temperatures to fluctuate or that the Atlantic Ocean's internal climate cycle (the Atlantic Multi-Decadal Oscillation) "may have played a role… leading to cycles with fewer or more hurricanes depending on conditions."[497] Ultimately, many climate scientists contend that climate change is likely intensifying already active hurricane seasons, making them more destructive and deadly, but the exact role it plays and how it interacts with many of these other systems is not entirely known.[498]

Climate scientists acknowledge that determining a clear causation between a single weather extreme, several of which took place during the 2017 Atlantic hurricane season, is difficult to do with certainty. The complexities of the climate system remain incredibly difficult to accurately predict on weather-relevant scales, even with the development of dynamic computing algorithms. However, "there is a vast and growing body of evidence that points toward global warming having an impact on the formation and severity of hurricanes."[499] The combination of warmer air, warmer oceans, and more suitable currents for hurricane development have played a key role in creating greater extremes within our planet's climate system. There is increasing evidence that such developments are strongly linked to climate change and are likely to worsen over time if nothing is done to mitigate greenhouse gas (GHG) emissions. However, even if drastic steps were immediately implemented by all nations to significantly reduce, if not stop, the emission of GHGs, the planet would still suffer from nearly a half-century of further warming and greater climatic volatility. The delay in reducing warming is due to the fact that GHGs, such as carbon dioxide, take decades to break down.

Therefore, short of a technological breakthrough that allows for large-scale carbon filtering of the atmosphere on a global scale—an unlikely prospect—the cities and regions across our planet that are most at risk to more severe weather systems and sea level rise must immediately pursue comprehensive adaptation strategies if they want to survive into the next century. As previously mentioned, there exists an array of particularly vulnerable U.S. cities, including: Tampa/St. Petersburg, Miami, New Orleans, Norfolk/Virginia Beach, and Houston. These cities already experience relatively high storm frequencies, are built on low lying terrain that is vulnerable to both flooding and storm surge, and are likely to experience significant effects from both sea level rise and greater storm strength and frequency due to climate change.[500] While damage from these

[494] Ibid.
[495] Ibid.
[496] Ibid.
[497] Ibid.
[498] Ibid.
[499] Jeffery Kluger, "5 Ways Climate Change May Be Making Hurricanes Worse," *Time*, September 8, 2017, http://time.com/4933743/hurricane-irma-climate-change-global-warming/.
[500] Freedman, "The 5 Most Vulnerable U.S. Cities to Hurricanes."

increasingly dangerous storms is unavoidable, improvements to adaptation infrastructure such as improved artificial and natural drainage systems, stricter zoning codes, and erosion control structures can help mitigate the worst of the impact and prevent some cities or regions from becoming uninhabitable.

From Harvey to Irma, the 2017 Hurricane season has brought to light the vulnerability and ill-preparedness of U.S. coastal communities. Climate change is making the atmosphere and oceans warmer, it is creating greater volatility in weather systems, and it is increasing the likelihood of more severe storms. Irma and Harvey have shown us that many of our cities and regions are extremely vulnerable to severe weather events that will likely occur with greater intensity in coming decades. Thus they must immediately implement adaptive strategies in preparation, or risk even higher costs of resources and human life in the future.

Part III: Implications

Chapter 13: Future Challenges

In this final chapter, we summarize the impact of fresh water scarcity on regional security, especially in the Middle East and Central and South Asia. After reviewing the impact of sea level rise, especially in the United States and low-lying nations, we survey the unique role of the U.S. armed services as a leader in addressing the national security elements of climate change. We also assess the potential domino effect that mass migration could have on national security and the subsequent growth in gated communities, the expansion of national barriers to limit population movement, and the inevitable trend towards a new 'Age of Enclosure.' We conclude with a discussion of the political and technological decisions that could help to mitigate these challenges.

Fresh Water Scarcity and Regional Conflict

A region's climate and environmental context can heavily influence a culture's development and evolution. Many of the cultural, social, and political practices in the world today grew from the specificities of the lands in which they developed. Rapid changes in a nation's prevailing environmental conditions may create not only environmental challenges, but severe social, political, and security tensions. Climate change can threaten the future of conventions binding together various populations and destabilize governments and societies. The current rate of change in the Earth's climate is unprecedented in human history and, as both a catalyst for conflict and threat-multiplier, climate change has serious consequences for the national and international security of individual nation-states and interdependent regions.

For the developing nations of Asia and the politically unstable Middle East, climate change is already posing tangible threats to freshwater security, from declining water tables to rising sea levels, drought, and soil degradation. These consequences portend a difficult future even for nations that are not currently facing issues of water scarcity, as their long-term outlooks may be troublesome without costly climate mitigation and adaptation efforts. Moreover, the rising costs of climate-related disasters and challenges are providing the rest of the world with a reminder of how a changing climate exacerbates existing problems and creates new ones.

In this century, one of the strongest examples of the links between climate change and human conflict is the civil instability following the 2006-2011 drought in Syria. Scientists have tied the drought, which was the most intense in the region in hundreds of years, to human-induced climate change, and widely believe that it was a primary factor in causing the migration of Syrians from rural to urban centers. This migration then seeded the social unrest which eventually culminated in the 2011 demonstrations and subsequent uprising against President Bashar Al-Assad. Since the start of the conflict, Syrians have been the largest group of asylum-seekers in the European Union, where nations are contending with a refugee crisis and cultural backlash. European discontent over accepting large numbers of foreign refugees manifested itself in support for populist, nationalistic, and isolationist politicians and policies—the effects of which are still playing out. Syria not only evinces a strong correlation between environmental factors and conflict, but also epitomizes climate-driven insecurity that can have far-reaching political consequences.

On the Arabian Peninsula, the ongoing conflict in Yemen threatens to create a failed, ungoverned state that will provide even more fertile ground for extremist groups. It comes at a time when Yemen is running out of oil and climate change and bad agricultural practices are depleting its scarce fresh water resources, which are frequently exploited by various actors seeking parochial ends. Saudi Arabia, alongside several foreign powers, has escalated tensions on the peninsula by intervening militarily, while refugee crises and the staying power of terrorist groups in nearby Iraq and Syria have increased the risk of interstate conflict. Compounding these progenitors of increased instability, climate projections point to progressing aridity and water-scarcity, which will likely lead to additional strife between and within states. Yemen serves as a bleak example of a humanitarian crisis that could occur at the intersection of geopolitical conflict and climate change. Prolonged conflict will undermine the government's ability to function and make action on climate change less feasible, even as the country suffers. Improving Yemen's water problem is possible in this age of advanced technology, agriculture, and management techniques, but without good governance and financial help, even a peaceful Yemen will face difficult economic choices to mitigate its extreme water crisis.

Competition for climate-threatened freshwater basins in the Middle East and in Central and South Asian countries is sparking disagreements or exacerbating already existing animosities between neighboring states. Nearly two-thirds of the world's transboundary rivers have no existing cooperative management frameworks, making future conflicts more likely.[501] Water sharing disputes are additionally complicated by climate change, which is further melting mountain glaciers—the origins of many great rivers—and intensifying general drying in already arid regions. In particular, the glaciers of Central Asia are the source of the disputed Indus River Basin and the Helmand River, and have been shrinking at a rapid pace that is expected to continue as the world warms. The projected decline in river flow downstream is certain to raise tensions among states that are reliant on current flow rates, especially as their populations grow. Additionally, rainfall in the Middle East is expected to fall 20 percent by the end of the century, and temperatures could rise by as much as 5 degrees Celsius.[502] This can have significant impacts on surface drying and groundwater resources, in addition to new stress on river output.

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[501] "Transboundary Waters," *United Nations-Water*, accessed March 22, 2018. http://www.unwater.org/water-facts/transboundary-waters/.

[502] Scott Waldman, "Climate Change May Have Helped Spark Iran's Protests," *Scientific American*, January 08, 2018, https://www.scientificamerican.com/article/climate-change-may-have-helped-spark-iran-rsquo-s-protests/ .

In some cases, such as the disputes between Sudan and South Sudan over the White Nile and between India and Pakistan over the Indus River basin, riparian disputes are worsening already tense relationships among neighbors. Disputed rivers such as the Helmand (contested by Iran and Afghanistan) and the Nile (used by nations like Egypt, Ethiopia, and Sudan) are also a source of dysfunction and animosity as upstream neighbors are rushing to develop dams for irrigation or hydroelectric power—leaving their downstream neighbors to contend with the reduced freshwater flow. As river freshwater sources are threatened by climate change and increasing population growth, riparian neighbors must be willing to cooperate or allow third-party arbitration to settle existing issues and plan for steadily decreasing resources. Disputes over riparian rights are currently creating or aggravating tensions between neighboring states and have the potential to affect regional stability, and thus the current balance of power in many regions. Rising temperatures and population growth are already spurring an increased freshwater demand in many of the world's most water-scare regions, leading to social unrest and increased resource rivalry. With climate change also decreasing the sources of many great rivers, tensions and conflict are more likely.

Sea Level Rise and National Security

In parts of the world threatened by sea level rise, including the United States and many low-lying and small island states, climate change is already having deleterious effects on the economic productivity with worrying implications for the global economy. Coastal cities like New York, Miami, and New Orleans contribute significantly to the U.S. economy as financial and cultural hubs, and will require billions of dollars in reconstruction as rising seas and stronger storms—both consequences of anthropogenic climate change—threaten their respective populations. By the end of the century, millions of Americans may be forced to relocate from their homes to escape rising tides, while outside of the United States, low-lying islands like the Maldives and the Marshall Islands will face existential threats. Many of those living on low-lying islands are taking the threats posed by climate change far more seriously than their counterparts whom live on the mainland; several governments of island nations are pressing for relocation funds and planning for the eventuality of a mass population migration. These island nations, teetering on the brink of submersion, should serve as a warning for low-lying, mainland territories, such as Bangladesh, that have more time to call attention to themselves.

Role of the U.S. Department of Defense in Understanding Climate and Security

Climate change will have significant impacts on U.S. national security by affecting military infrastructure, an issue that will afflict other countries as well. The United States Department of Defense (DoD) has been a leader within the country in addressing the connection between climate and security, and several documents put out by the department over the years have attested to its fundamental recognition that climate change will negatively affect the U.S. military. In this respect, the DoD, especially the armed forces, may be one of the U.S. government agencies most able to undertake an objective approach to assessing climate change amidst political controversy.

The most recent Quadrennial Defense Review (QDR) published by the Department of Defense in 2014 recognizes climate change as a threat to the Department's achievement of the goals described in its three pillars: "protect the homeland," "build security globally," and "project

power and win decisively."[503] The QDR puts forth a myriad of ways in which climate change may affect the DoD's ability to fulfill its mission: "The impacts of climate change may increase the frequency, scale, and complexity of future missions, including defense support to civil authorities, while at the same time undermining the capacity of our domestic installations to support training activities."[504] The DoD, thus, has committed to investing in "energy efficiency, new technologies, and renewable energy sources" in the hopes of preparing for a "future security environment where logistics may be constrained."[505]

The DoD has taken several steps to identify the ways in which climate change could potentially impact its infrastructure and operations. In July 2015, the DoD produced the report "National Security Implications of Climate-Related Risks and a Changing Climate" for the Senate Committee on Appropriations. The report identified four focal areas of climate-related risks: "Persistently recurring conditions such as flooding, drought, and higher temperatures," "more frequent and/or more severe extreme weather events," "sea level rise and temperature changes," and "decreases in Arctic ice cover, type, and thickness."[506] The first three risks all have the potential to "dampen economic activity" in affected locations, as well as to prompt human migration to more habitable areas. Large-scale migrations and humanitarian crises may create political pressure to have the U.S. military engage in costly humanitarian aid operations and disaster-relief programs. Sea level rise also carries a direct threat to military infrastructure from flooding and weather events.[507] The fourth security risk, "decreases in Arctic ice cover, type, and thickness,"[508] presents an unprecedented scenario in which the Arctic Circle is increasingly accessible to a variety of actors: tourists, commercial shipping lines, resource extraction companies, and foreign militaries. Due to the unfamiliar nature of this potential reality, the DoD recognizes the need for further evaluation when it comes to its current "Arctic capabilities."

In 2018, the DoD identified U.S. military installations with existing vulnerabilities to climate and weather. This report surveyed 3,500 military properties and reported that weather had a significant detrimental impact on 782 sites affected by drought, 763 by wind, 706 by non-storm surge related flooding, 351 by extreme temperatures, 225 by storm surge, and 210 by wildfire.[509] The U.S. military is thus already contending with multiple effects of extreme weather conditions and acknowledging its costly nature, signaling the beginnings of potentially increasing expenditure on climate change adaptation.

Within the Department of Defense, the institutions most deeply involved in anticipating the negative impact of climate change on U.S. national security are the armed forces. The Joint

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[503] U.S. Department of Defense, *Quadrennial Defense Review*, 2014, http://www.defense.gov/Portals/1/features/defenseReviews/QDR/2014_Quadrennial_Defense_Review.pdf.
[504] Ibid.
[505] Ibid.
[506] U.S. Department of Defense, *National Security Implications of Climate-Related Risks and a Changing Climate*, 2015, http://archive.defense.gov/pubs/150724-congressional-report-on-national-implications-of-climate-change.pdf?source=govdelivery.
[507] Ibid.
[508] Ibid.
[509] U.S. Department of Defense, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. *Climate-Related Risk to DoD Infrastructure Initial Vulnerability Assessment Survey (SLVAS) Report,* Washington, D.C.: DoD, January 24, 2018, https://climateandsecurity.files.wordpress.com/2018/01/tab-b-slvas-report-1-24-2018.pdf.

Chiefs of Staff and the uniformed heads of the Navy, Marine Corps, Army, and Air Force are the best suited to argue the case for the reality of climate change impacts and for the long-term preparations needed to meet the potential threats posed by rising sea levels, extreme weather conditions, conflict caused by migration due to loss of habitat, and weakened governance.

Migration and the Age of Enclosure

Transformations in the environment caused by climate change have the potential to spur massive human migrations from areas that are no longer able to sustain a decent standard of living to areas deemed more habitable. Difficulties arise when the more habitable domains are across state borders, in areas where citizens may speak a different language, have different customs and laws, or more importantly, are unaccepting of foreigners. When migrations from developing to developed nations occur, combined with the growing asymmetry of wealth between the rich and poor, they trigger the development of new "walled worlds." Barriers along borders, within countries, and the proliferation of gated communities have contributed to the spread of enclosures and other physical structures solely designed to keep people out. Globalization presumes easier communications and exchanges between and within countries, but this phenomenon raises the prospect of a selective reversal of those processes. As the plight of refugee communities worsens globally, we will see a decline in interconnectedness as those who have the most resources and capabilities to resolve crises also have the most incentive to isolate themselves from the disruptive effects of migration.

There are important implications associated with the spread of enclosures: economic costs from increasing international isolationism, a potential loss of civil liberties in democratic societies, and the empowerment of more authoritarian governance. At the national level, governments will have an increasing incentive to establish advanced border controls and monitoring systems, which could come at the expense of civil liberties in democratic societies or empower authoritarian strongmen elsewhere. At the international level, states will have an increasing incentive to close borders and isolate themselves from global policy challenges, with potentially devastating effects for economically interdependent regions that are reliant on open borders and freedom of movement, especially less developed regions that depend upon wealthier neighbors. Getting states to work together to address global policy issues, such as climate change or refugee movements, will only become more difficult over time. On the one hand, the spread of enclosures will be symptomatic of developed nations choosing disconnection and isolation over engagement and investment, and could mean an end to global economic and security regimes that have prevailed since the end of World War II. Yet, on the other hand, blocking the private development of enclosures also means restricting freedom.

Gated communities first appeared in the United States at the end of the nineteenth century, as enclaves for super-rich industrialists and bankers looking to escape the rapid urbanization occurring in major cities at the time, and who did not want to share communal spaces with the lower class. The appearance of Tuxedo Park in New York and "private streets" in St. Louis were the beginning of communities founded on exclusion. Gated communities' association with wealthy lifestyles has caused them to become popularized throughout all class structures, and upwards of

9 million homes in America are within gated communities today.[510] America pioneered the gated community, but it is now a global phenomenon and has taken on a variety of local forms. In many places, the perceived value of the gated community is as much about protecting one's life as it is about protecting one's lifestyle.

For example, a rich professional living in Pakistan is likely to settle into one of the new gated communities springing up near the big cities. These communities provide security and access to vital services such as electricity, clean water, and sewage, all of which the country has had extreme difficulty providing. Due to the combination of growing income inequality as well as prolific crime and terrorism, Pakistan has become the newest and fastest-growing market for secure, self-sufficient residential areas. The emblematic "Bahria Town" developments have locations near Lahore, Islamabad, and Karachi that offer both apartments and plots of land to those who can afford them, away from the poverty and degrading infrastructure of Pakistan's major cities.[511] What is going on in Pakistan is emblematic of the growing proliferation of gated communities globally. The Israeli West Bank settlements (the largest one is ultra-Orthodox Modi'in Illit with a population of 60,000),[512] Brazil's "*condominio fechado*" (Alphaville, part of greater Sao Paulo, has an estimated 60,000 residents and its own business district, schools, and hospital),[513] and South Africa's "security villages" (first appeared with the explosion of crime post-apartheid and their total number increased by 153 percent from 1998-2005)[514] are all distinguished from most American gated communities by heavier security, and a greater commitment to built-in self-sufficiency within the walls.

As climate-related security challenges exacerbate refugee flows, gated communities may become more prevalent as those seeking to protect their lifestyles become more insular. The preferred destination of refugees will be North America and Europe; however, the prosperity that makes these regions attractive to refugees also means they have the most resources available to devote to forming exclusive communities. If this occurs, it could contribute to a breakdown of societal norms, and access to the best public services, security, and healthcare would be even further limited to the wealthy elite. This would likely fuel ethnic and class divisions, as well as exacerbate political problems enhanced by existing tensions based on ethnicity, religion, or nationalism. These exclusionary practices may potentially reinforce nationalist politics and ideologies, leading to a shift in domestic politics towards policies that allow for insulation from external global challenges.

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[510] "2015 American Housing Survey," *U.S. Census Bureau*, December 21, 2017, https://www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html#?s_areas=a00000&s_year=n2015&s_tableName=TableS03&s_byGroup1=a1&s_byGroup2=a1&s_filterGroup1=t1&s_filterGroup2=g1&s_show=S.

[511] Meher Ahmad, "Pakistan's White-Picket Fences," *The Outline*, February 19, 2018, https://theoutline.com/post/3454/pakistan-suburbs-bahria-town-malik-riaz?zd=1&zi=3xj67auc.

[512] Jodi Rudoren and Jeremy Ashkenas, "Netanyahu and the Settlements," *The New York Times*, March 18, 2015, https://www.nytimes.com/interactive/2015/03/12/world/middleeast/netanyahu-west-bank-settlements-israel-election.html.

[513] Jonathan Watts, "Walled World: The Rich-Poor Divide," *The Guardian*, November 19, 2013, https://www.theguardian.com/world/ng-interactive/2013/nov/walls#intro.

[514] "South Africa's 'Security Villages' Provide Little Protection for Residents," *South China Morning Post*, February 20, 2013, http://www.scmp.com/news/world/article/1154082/south-africas-security-villages-provide-little-protection-residents.

An increasing number of countries sharing borders with impoverished and unstable neighbors have taken strong measures to prevent illegal immigration. This means building bigger and more effective walls and fences with high technology surveillance systems, guard posts, and physical patrols on the ground, in the air and at sea.

The most salient examples of newly erected barriers are those that have been formed in response to the Syrian refugee crisis. Beginning around September of 2015, Hungary emerged as the European country most hostile to Syrian refugees when it announced its plan to construct a barrier fence along its southern border with Serbia, as well as three-year prison sentences for migrants caught attempting to cross it.[515] Serbia, Croatia, and Slovenia have followed suit, and have forbade migrants without EU visas to enter the country, directly targeting refugees and asylum seekers. While the flow of refugees has slowed down, bottlenecks still exist at the borders of countries that act as gateways to the rest of Europe, as well as making it possible for smugglers to charge even more for their services.

As many European countries turn to fortifying their borders rather than opening them up, this has jeopardized the lives of those fleeing the atrocities of civil war. Eventually, however, European liberal values and their modern pillars of inclusiveness and cohesion may be sacrificed as well. The Syrian refugee crisis has sparked the anger of European nativist parties, whose party platforms are founded on the basis of excluding immigrants and maintaining the homogeneity of their respective countries, for fear that with the acceptance of immigrant and refugee quotas will come increased terrorist attacks and chaos. As was revealed on June 23, 2016, the United Kingdom too felt that what was best for the country was not stronger ties with the EU, but rather a break in them altogether.[516] The U.K. is not the only country currently showing a preference for exclusion over inclusion and mutual commitment, in a time when millions are left stranded, in fear for their lives.

Along its border with Egypt, Israel has created a border fence so massive that it is visible from space, and Saudi Arabia has begun construction of a 965 km (600 mile) long wall along its border with Iraq in response to the threats of the Islamic State and a 1,170 km (1,100 mile) long wall along its border with Yemen in response to threats from Houthi forces.[517] India has built an enormous 2,000 km (1242.7 mile) fence around most of overpopulated Bangladesh for fear of being overwhelmed by refugees, if and when the next natural catastrophe hits its overcrowded neighbor.[518] As global refugee movements are intensifying, particularly in response to conflicts and events which climate change is expected to intensify, the reliance on increased border control will increase. Rising sea levels around the world will flood coastal areas and destroy farming and fishing, along with droughts and floods putting pressure on would-be migrants to seek refuge in neighboring countries.

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[515] Marton Dunai, "Hungary Sentences 10 Migrants for Illegal Border Crossing," *Reuters*, July 1, 2016, https://www.reuters.com/article/us-europe-migrants-hungary-court/hungary-sentences-10-migrants-for-illegal-border-crossing-idUSKCN0ZH4DP.

[516] Alex Hunt and Brian Wheeler, "Brexit: All You Need to Know About the UK Leaving the EU," *BBC*, March 3, 2018, http://www.bbc.com/news/uk-politics-32810887.

[517] Michael Rubin, "Trump's Border Wall is Standard Practice in Other Parts of the World," *Washington Examiner*, January 23, 2018, https://www.washingtonexaminer.com/trumps-border-wall-is-standard-practice-in-other-parts-of-the-world/article/2646819.

[518] Ibid.

Global refugee flows like what are already occurring in Europe will put a serious strain on the capabilities and availability of social services in developed nations. The likely response that these nations will take will be similar to what Pakistan has already implemented in the form of "Computerized National Identity Cards" (CNIC). These cards are used to store personal information about every resident, and ensure that those who are not eligible to receive publicly funded services do not. The European Union has already invested in such a system through its "Smart Borders" program. Smart Borders would offer the EU the ability to track the entry and exit of travelers, residents, offer information about over-stayers or other persons who are in the country illegally, while reinforcing domestic security and helping prevent serious crime and terrorism.[519] The European Commission, in the proposal for the new Smart Borders Entry/Exit System (EES), recognizes that Europe faces an ever-growing number of "travelers" who are not EU nationals, and through the EES hopes to combat the influx of migrants by improving the efficacy of Schengen Area border controls. The use of these systems will give governments increased authority to manage people's personal information and determine their compliance with the law. Increased border controls and restrictions at the national level have the potential to go hand in hand with nationalist sentiment and authoritarian ideals, further bolstering support for nativist parties and making countries more insular. For wealthy states that have already successfully established "smart borders" and can easily track the flow of persons through their countries, adopting policies of tightening borders will be more attractive than investing in solutions that stop refugee flows at the source.

Developments in 2015-2016 surrounding the European migrant crisis have raised doubts regarding the viability of the Schengen agreement. The agreement was signed in 1985 by Belgium, France, West Germany, Luxembourg, and the Netherlands and became effective in 1995, when the area free of internal border checks was created. Following an exceptional influx of migrants, several signatory states such as Austria, Denmark, Germany, Norway, Poland, and Sweden have reintroduced border controls between themselves and other members of the Schengen Area.[520] Hungary has been at the forefront of efforts to strengthen border security, going as far as constructing a border fence along its border with Serbia and Croatia in an effort to close the Balkan migration route. While Croatia, Bulgaria, and Romania are not yet full members of the Schengen area, the countries have been certified to have fulfilled their legal obligations to join the agreement, but ongoing domestic political concerns and international territorial disputes have made such an accession highly unlikely.[521] Criticisms of the Schengen agreement have become part of mainstream European politics, and are only likely to become more prevalent as populist and nationalist parties gain power throughout the continent.

At an international level, the increasing incentive for states to isolate themselves from refugee movements could lead to a fundamental shift in how nations approach policy issues. States that are facing difficult policy challenges globally may find the solution of border controls and

[519] Anita Orav and Alessandro D'Alfonso, "Smart Borders: EU Entry/Exit System," *European Parliamentary Research Service*, January 12, 2018, http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/586614/EPRS_BRI(2016)586614_EN.pdf.
[520] "Temporary Reintroduction of Border Control," *European Commission*, March 12, 2018, https://ec.europa.eu/home-affairs/what-we-do/policies/borders-and-visas/schengen/reintroduction-border-control_en.
[521] Andra Timu, "Juncker Calls for Romania, Bulgaria to be Admitted into Schengen," *Bloomberg Politics*, September 13, 2017, https://www.bloomberg.com/news/articles/2018-03-12/mueller-is-said-to-weigh-putting-off-trump-obstruction-decision.

isolation to be preferable. When it comes to global policy issues, "do nothing" is always a valid response, and having secure borders often makes it a far more attractive solution than risky engagements. However, climate change and its associated challenges are global issues, and require global responses. America cannot unilaterally prevent greenhouse gas emissions, Germany cannot take in every refugee, and Norway cannot fund every development project. The Paris Agreement, initially signed by 195 countries in December of 2015 proved that a multilateral climate agreement was possible. However, a recent Trump administration decision to take the United States out of the Paris Agreement has created uncertainty around its longevity, though initial statements by participant countries in Asia and Europe strongly condemned the U.S. administration's actions and reaffirmed their own commitments.[522]

A key goal described in the Paris Agreement revolves around climate "adaptation," whereby the international community commits to support both developed and developing countries in dealing with the impacts of climate change. To achieve this goal, wealthier states have agreed to provide funds to the "Green Fund" in order to assist less developed nations that are the most vulnerable to climate change but least capable to adapt. This broad objective certainly considers the fact that a changing climate will require countries to make large-scale changes to their societies, but it does not address the inevitable situation in which citizens have to relocate themselves and their families. As certain areas of the world become less inhabitable, and migrants continue come to Europe from Iraq and Syria (areas where climate change-induced drought can be directly linked to the civil war and strife that is causing outflows of refugees), it remains to be seen whether the countries that signed the Paris Agreement will stay true to their commitment to supporting countries in need of "adaptation" or if they will turn to isolationism. As the costs of addressing issues such as food and water insecurity, migration, and natural disasters rise, it is possible more states will reach the conclusion that such investments are not worthwhile. Yet, while the upfront costs of assisting less developed states with climate adaptation needs may appear costly and detrimental to the economies of more developed states, the long term financial and security costs of inaction may prove far greater and could grow exponentially larger the longer we wait.

While physical border protection and isolationist immigration policies might be a necessity of democratic politics in many developed countries, it is crucial to separate such actions from other forms of international cooperation. Global institutions, such as the UN, are reliant on the capacity of member states to participate, fund, and enforce institutional operations, which will only increase in importance as climate change imperils many regions of the world. It is therefore important that, even when enacting physically isolationist policies, countries refrain from engaging in political and economic isolationism that could prevent a cooperative response to climate change.

The importance of respecting national sovereignty and public sentiment must also be recognized. It is irrefutable that the uncontrolled migration of large populations has the potential to negatively affect developed countries. It is also undeniable that the citizens of many of the latter countries simply do not desire such uncontrolled migration, as the popular response to the migration of refugees in Europe has demonstrated. Attempts to ignore democratic expressions of opinions related to migration will only result in popular anger aimed at international institutions, possibly provoking an unfortunate rise in nationalism and politico-economic isolationism.

[522] Somini Sengupta et al., "As Trump Exits Paris Agreement, Other Nations Are Defiant," *The New York Times*, June 1, 2017, https://www.nytimes.com/2017/06/01/world/europe/climate-paris-agreement-trump-china.html.

Attempts to impose on unwelcoming populations under the pretext of solidarity and international responsibility is therefore shortsighted and will likely lead to further isolation in the medium to long term.

The security challenges of the future will be increasingly defined by political instability exacerbated by climate change. The direct consequences of climate change on resource scarcity and infrastructure vulnerability are likely to have a ripple effect. As resources such as food and water become more vulnerable and scarce, non-state actors in arid regions may attempt to seize these resources to establish legitimacy and control. The vulnerability of infrastructure, particularly as it relates to military basing, might encourage retrenchment just as the need for engagement is increasing. Global migration, fueled by conflicts, will probably increase ethnic tensions and civil strife even in the developed world. The inability to collectively address these problems will put a strain on liberal ideology in political environments defined by intensifying widespread conflict. Unfortunately, these consequences of climate change receive little attention in the political sphere, and there are significant consequences of continued apathy, which are not being factored into decision-making.

With more countries today working actively to ensure the most efficient and protective measures for securing their borders, it is important to analyze the political consequences of an increasingly "walled world." The need for border security has reinforced the existing gap between the rich and poor on both the international and domestic level. This brief review of the new world of walls, gates and high technology presents a serious challenge for democratic societies whose basic principles are meant to value integration rather than segregation. The expectations that climate change and environmental disasters will increase in the coming decades suggest this trend in exclusion and enclosure will increase. But if the more dire predictions of the climate scientists become reality sooner rather than later, the international community may be forced to examine the issue and its many ramifications on a global scale with global policies to minimize the negative effects that are already happening. Desperate times can, in theory, contribute to cooperation. At least, one hopes they can.

Political Challenges

Despite the scientific consensus, climate change has been an extremely contentious political issue for decades. The only acknowledged low-risk, permanent solution is to phase out greenhouse gas (GHG) emissions, but doing so requires uprooting existing infrastructure in virtually every sector of the economy. Because of its extensive and costly nature, policymakers often do not place the fight against climate change at the forefront of their policy platforms. Politicians often frame the discussion in the context of the economic costs of mitigation and adaptation, rather than considering the security costs of inaction or the potential economic gains from the development of new technologies and industries.

Climate change has an unfortunate history in the political sphere. The complexity of the issue makes it difficult for scientists to single out and precisely quantify its effects, and oftentimes the most serious consequences of climate change—such as intensified extreme weather events—cannot be attributed individually to climate change. For years the science of climate change has been called into question in the United States, and a fringe of climate denial still exists in mainstream media, thought, and politics. The concept of "uncertainty" in climate models has been

substantially inflated in political discourse, and has been made into an argument for denial instead of a reason for making hedged, informed decisions for a range of future climate scenarios. As with weather forecasting, the probabilistic and imperfect science of prediction does not disqualify the compelling, foundational understanding of how the climate may evolve with increasing atmospheric greenhouse gas concentrations emitted by industrialized humanity.

Policies focused on reducing GHG emissions have often been perceived as being too costly and disruptive to pursue, making them difficult to defend politically when the consequences of climate change seem nebulous and distant to the layman. However, mitigation policies do not have to be cost prohibitive. If the externalities of GHG emissions are accurately priced into the market, consumers would be incentivized to avoid high emissions goods, which would drive innovation towards reducing emissions even further. Although this would raise energy prices in the short term, they will hopefully decline over time as new innovations make renewable energy sources more affordable. The most disruptive effects of policies that reduce GHG emissions would be on entrenched industries that profit from the status quo as well as the consumers which rely on them. On the other hand, policies that reduce GHG emissions have the potential to provide economic opportunity for those states and industries that are the fastest to adapt to changes in policy, consumer preferences, and technological advancements.

In an attempt to meet stated climate objectives for the United States, President Obama announced new regulations on emissions, with an estimated cost of $230 billion USD, to abate an average temperature increase of less than 0.2 degrees Celsius.[523] When facing the economic impact of regulation, it is easy for those opposed to climate action to make the case for investing in adaptation rather than mitigation. Focusing on global emission reduction is difficult to defend politically, as it relies on the cooperation of numerous foreign actors over whom policymakers have no control. Nonetheless, collective problems require collective action, and when a state is a faced with a problem that is collective in source and transboundary in effect, it is in its own self-interest to work with others to resolve the issues. All states need to set goals, build trust, and move toward more ambitious goals over time. This premise was the basic rationale behind the framework of the Paris Agreement.

Wealthy states are also the most economically capable of supporting a policy focused on adaptation. Strong economic growth to improve adaptability is sometimes seen as a preferable, more certain investment in climate and security. This has resulted in a paradox, where the developed, high emissions states that are most critical to overcoming the challenges associated with climate change are also the most reluctant to adopt policies that are economic costly in the short term, but potentially economically beneficial in the long term and necessary to slow warming trends. This supports the argument that the key to persuading states to increase investment in global climate action is by focusing on both the security implications and the potential economic benefits from proactive policies to address climate change.

Despite the scientific consensus, the politics surrounding climate change has made collective adoption difficult domestically and internationally. The global scale of climate change

[523] Sam Batkins. "Previewing Paris: U.S. to Spend Additional $38 to $45 Billion to Meet 2025 Goals," *American Action Forum,* October 28, 2015, http://americanactionforum.org/research/previewing-paris-u.s.-to-spend-an-additional-38-to-45-billion-to-meet-2025.

demands a correspondingly global response, so policy has been steered towards a focus on international agreements to legally bind nations to reduce emissions. The culmination of these initial efforts was the 1997 Kyoto Protocol, the world's first legally binding climate agreement, which best exemplified the difficulty of achieving both inclusion and compliance in a global climate agreement. The protocol placed the burden of carbon emission cuts entirely on developed nations but imposed no restrictions on developing nations like China and India under the rationale that they ought to have the right to reap the benefits of industrialization that developed nations had already enjoyed. However, because states face the consequences of climate change regardless of their participation in global agreements, this approach leaves both the burdens of responsibility and the consequences of failure distributed unevenly and incentivizes some states to 'freeride' on the carbon reduction efforts of others. This, together with the U.S. withdrawal from the Protocol, has resulted in its failure to stop growth in GHG emissions.

Global climate policymakers have since learned from the failures of the 1997 Kyoto Protocol. The 2015 Paris Agreement focuses on technology and voluntary commitments, recognizing that without affordable low-emission energy, no agreement can bind states to costly energy policies. The success of this approach remains to be seen. However, experts note that the GHG cuts currently proposed by the major emitting states will still be insufficient to avoid reaching 2 degrees Celsius of warming (a point of warming beyond which the IPCC anticipates significant negative consequences).[524] States are moving towards more cooperation on climate change issues, but their pace of action is glacial.

The international fight for reducing global anthropogenic GHG emissions comes at a difficult time as the human population is continuing to grow and national economies are rapidly expanding. Policies focusing on reducing emissions must address the carbon that is being currently emitted by existing infrastructure as well as the expected increase in the further development of that infrastructure. However, the longer the wait to reduce emissions, the greater the cost to mitigate and adapt. Since the severity of the issue will be greater the longer action is held up, the speed of change will have to be quicker and therefore costlier in the short term in order to avoid climate change's most damaging effects.

The Role of Technology and Market Forces

Effectively addressing climate change must ultimately be rooted in both sound policy and timely technological advancement. However, technological advancement does not always take place ahead of its own necessity, but instead in response to market forces. It is crucial that policymakers and the public first recognize the problem, which must also be quantified to assist in the development of efficient and lasting policies that promote technical breakthroughs in the energy sphere, especially in the realm of efficiency and the ability to scale-up to the needs of large populations. Two efforts should be simultaneously pursued to achieve this end: first, public opinion must be educated about how carbon emissions adversely affect their health, the economy, and national security through climate change and pollution, and second, policymakers should use this same information to promote the accurate pricing of electricity and goods that use carbon as a significant input.

[524] Michael Greshko, "Current Climate Pledges Aren't Enough to Stop Severe Warming," *National Geographic,* October 31, 2017, https://news.nationalgeographic.com/2017/10/paris-agreement-climate-change-usa-nicaragua-policy-environment/.

These two policies should help encourage the incipient shift in private investment from fossil fuels to renewable energy technologies, and will make carbon capture and storage (CCS) technologies less expensive relative to current energy prices. Informing the public on how their tax dollars are spent rebuilding communities destroyed by natural disasters and absorbing medical costs as a consequence of excessive carbon emissions may create public pressure for low-carbon energy alternatives. CCS technologies will be critical to achieving decarbonization, or reducing the amount of carbon emissions released into the environment as a result of electricity generation, while meeting rising global energy demand. Relying on a diversified combination of renewable and low-carbon energy resources will be more feasible and affordable than comprehensively forsaking all fossil fuel energy sources.[525] The more progress that is made on making renewable energy sources cheap, clean, and plentiful, the less relevant wrangling over the cost of emission reductions will be to global politics. This technology-first framing ought not to be held up as a market-forcing solution excusing inaction on climate policy. Rather, it must be the basis for the political motivation behind timely and effective policy action. In understanding the gap between existing technologies and what is actually needed to significantly cut GHG emissions, one can see the necessity for governments to fund, incentivize, or otherwise spur further energy innovation and development.

The world is currently in a race against the clock: either clean energy will be developed and adopted in time, or the world will suffer from the egregious consequences of climate change stemming from resource insecurity and global migration. Timely, successively building advancements in climate-mitigation technology are unlikely to emerge without strong political support. Yet if the consumer is properly incentivized to purchase goods and services that reduce climate impact through the incorporation of GHG externalities, then industries will be equally incentivized to competitively pursue technological breakthroughs. Yet other complications will arise from this effort. Society's poorest members will be most adversely and disproportionally affected by the rising costs for electricity that consumers will have to pay for. Likewise, there is a time lag in which lower-carbon substitutes will not be readily available. While there is no immediate solution for the issue of time lag, a tax on carbon-based products could create revenue that could be spent to offset the damage done to poor communities and to fund low-carbon infrastructure and power generation. Ultimately, for any innovative solution to emerge there must be a large window of opportunity and potential market. The less action taken domestically and globally to reduce emissions by pushing the limits of existing technology, the smaller the window of opportunity will be for further technological innovation.

Thus far, contemporary discussions on climate change in the United States have failed to mobilize the necessary political will to achieve meaningful mitigation of carbon emissions. The hurdles disrupting progress are primarily political. Political arguments over this issue may be ideological in nature but they are economic at their core. Over the long term, the collective security threat posed by climate change is likely to have a greater financial cost than actions of mitigation and adaptation. Climate change adaptation therefore hinges on sound policy and public understanding of the collective security risks and the global benefits to burden sharing.

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[525] Jesse D. Jenkins and Samuel Thernstrom, "Deep Decarbonization of the Electric Power Sector: Insights from Recent Literature," *Energy Innovation Reform Project*, March 2017, http://www.innovationreform.org/wp-content/uploads/2018/02/EIRP-Deep-Decarb-Lit-Review-Jenkins-Thernstrom-March-2017.pdf.

Appendix

Weather and War: Historical Examples

To bring some perspective to the current debates about climate and security, and the potentially highly disruptive change that could descend on planet earth, it is always useful to look to history. The climate dilemmas we face today, while primarily caused by human activity since the Industrial Revolution, have parallels in the past. This appendix contains several examples of how anomalous weather occurrences led to the fall of some empires and the survival of others, with profound consequences for global politics. With the Earth experiencing continued warming and rising sea levels, the effects of climate change will increase both the severity and unpredictable nature of weather patterns, impact the strategic environment in many ways, and become an even greater factor in military planning.

One of the more intriguing examples concerns the cumulative events that are believed to have led to the end of the Bronze Age over 3,000 years ago. According to archaeologist Eric Cline, the collapse of the Later Bronze Age civilizations in the Mediterranean and Middle East in or around 1177 BC can be attributed to a "perfect storm" of catastrophes.[526] These included earthquakes, droughts and famine, mass migration, invasions, and internal rebellions. They resulted in the end, or the extreme diminishment, of key civilizations including Egypt, Babylon, the Minoans and the Mycenaeans, the Hittites, and coastal cities of Canaan such as Gaza and Jaffa. These entities had strong economic links between them, and traded with places as far away as Afghanistan for tin, which, combined with copper from Cyprus, was necessary to make the most desirable type of bronze, the key resource of the period. While copper supplies were plentiful, tin was a much more rare commodity and any interruption in the supply of tin had a strong economic impact on the bronze market.

Cline's book, together with high-resolution pollen analysis and radiocarbon dating of stalagmites in Cyprus, Syria, and Israel, strongly suggests that an intense drought contributed to

[526] Eric Cline, *1177 BC: The Year Civilization Collapsed* (Princeton, NJ: Princeton University Press, 2014).

the instability preceding and following the collapse of Late Bronze Age civilizations.[527,528] The change in climate may very well have led to crop failures, famine, and forced migration among civilizations heavily dependent on sustainable agricultural practices. Israel Finkelstein, an archaeologist at Tel Aviv University, contends that, "… groups of people in the northern regions were uprooted from their homes because of destruction of the agricultural output, and [they] started moving in search of food. They could have pushed other groups to move by land and sea. And this in turn caused destruction and disruption of the delicate trade system of the eastern Mediterranean."[529]

During this same period there are historical references to the so-called "Sea Peoples"—groups of marauding refugees seeking respite from famine who attacked cities near the coasts. They are widely considered to have posed a challenge too great to bear for the increasingly insecure Eastern Mediterranean civilizations of the Late Bronze Age. The Sea Peoples are still a mystery to archaeologists who debate their origins and ethnicities—but most agree that they eventually laid waste to the cities of the Eastern Mediterranean, including modern Israel. Some historians believe that the Sea Peoples were outlying nomadic groups who ventured into this territory as a direct result of the same regional climate-driven food insecurity postulated to have been affecting the Eastern Mediterranean.[530]

Cline suggests that no one event—earthquakes, droughts, migration, rebellion, and invasion—alone could cause the collapse of the most sophisticated political and economic system ever seen on the planet. But taken together over a relatively short period of time, the "perfect storm" of these events caused the empires and civilized enclaves to succumb to a domino effect that was decisive in its outcome despite the complexity of its causes.[531] The details of the events of 1177 BC may be very different from the dramas that are occurring in the Middle East and other regions today, but they show clearly that when order is replaced by anarchy, civilizations vanish and a new dark age descends.

Weather and climate factors continued to play a major role in military campaigns into the common era, as the Mongol conquest of Japan was stymied by one such event. Genghis Khan and his descendants swept over the Central Asian steppe in the 13th century, establishing an expansive empire. After Genghis Khan's grandson Kublai Khan came to power in 1260, he ruled over an empire that occupied one fifth of the world's inhabited land. In his seemingly insatiable need for more territory, Kublai Khan turned his attention to the islands of Japan and, in 1274, launched a massive amphibious invasion of the Japanese mainland. Vastly outnumbered and possessing inferior weapons, the situation for the Japanese appeared dire. Despite these odds, the Japanese were saved by a typhoon that destroyed much of the Mongol fleet at sea and prevented the invasion. Undeterred, Kublai Khan assembled a new fleet of 4,400 ships and returned in 1281 with 40,000

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[527] David Kaniewski et al., "Environmental Roots of the Late Bronze Age Crisis," *PLoS ONE* 8, no. 8 (2013): E71004.
[528] Martin Finné, Karin Holmgren, Chuan-Chou Shen, Hsun-Ming Hu, Meighan Boyd, and Sharon Stocker. "Late Bronze Age Climate Change and the Destruction of the Mycenaean Palace of Nestor at Pylos." *PLoS ONE* 12, no. 12, E0189447.
[529] Roff Smith, "Drought Led to Collapse of Civilizations, Study Says," *National Geographic*, October 25, 2013, https://news.nationalgeographic.com/news/2013/10/131024-drought-bronze-age-pollen-archaeology/.
[530] Kaniewski et al., "Environmental Roots of the Late Bronze Age Crisis."
[531] Cline, *1177 BC: The Year Civilization Collapsed.*

troops.[532] Again, Japan was saved by a timely typhoon, which once more decimated the Mongol fleet. These two typhoons, also known as *kamikaze*, meaning "divine wind" in Japanese, ultimately prevented the Mongol takeover of Japan and its subjugation to foreign rule, which would have significantly altered the future governance and history of Japan and East Asia.

Three hundred years later, "divine winds" were again the key reason for the defeat of a major power intent on continental domination. This time, stormy seas caused the destruction of the Spanish Armada, launched against England in 1588. Phillip II of Spain was a bitter enemy of Queen Elizabeth I of England; their rivalry fueled both by the conflict between Spanish Catholicism and English Protestantism as well as English support for the Dutch Revolt against the Spanish, which began in 1566. An Armada of 130 ships was assembled at the Spanish port of Coruña and left for England in August of 1588. The mission was simple: escort the Spanish Army based in Flanders and end the rule of Queen Elizabeth I in England, and with it, Protestantism in the British Isles. In turn, this would end British interference in the Spanish Netherlands and the Spanish possessions in Latin America.

After leaving Coruña, the Armada anchored in the English Channel near Calais. Driven around the British Isles by English attacks and unfavorable wind conditions, the fleet was in total disarray. Ordering the fleet back towards Spain, the Duke of Medina Sidonia turned the Armada into a series of terrible storms. The "Protestant Wind," as the storms are often referred to, led to the destruction of the Armada. Over a third of the Spanish ships failed to return to port, resulting in the death of 20,000 men and altering the course of European history.

The fate of Napoleon Bonaparte and his European empire was also partly determined by weather conditions. Under the auspices of "Polish liberation," Napoleon invaded Russia in June of 1812 with a Grande Armée of 680,000 soldiers. Napoleon pursued the retreating Russian force farther and farther into the Russian interior over the succeeding months, but despite winning victories at Borodino and Maloyaroslavets and even taking Moscow, the Russian winter proved his better. His defeat at the hands of the Russians was incurred in large part due to the frigid Russian winter, which wreaked havoc on the over-extended French supply lines and starved and froze its soldiers. By November 1812, only 27,000 French troops remained. Their failure not only saved Russia from Napoleonic rule but also signaled a major shift in the European balance of power. As a result of Napoleon's perceived weakness, Prussia and Austria broke off alliances with Paris, greatly diminishing France's power in the region.

The weather's wiles also sealed Napoleon's final downfall at Waterloo. After his escape from Elba, Napoleon marched toward modern-day Belgium to destroy a coalition of English, Dutch, and Prussian units that had formed against him. Meeting at near Brussels at Waterloo, the two forces clashed on June 18th, 1815. Described by the Duke of Wellington as, "the nearest-run thing you ever saw in your life," the battle was closely contested, but the torrential rains ultimately gave the coalition forces the upper hand. Although both armies were inundated by fierce storms the night before, the coalition troops held higher ground on the battlefield, meaning that the ground beneath them was comparatively drier. Conversely, the French were mired in ankle deep mud, which reduced their maneuverability vis-à-vis the coalition armies. This denied Napoleon his

[532] Peter Shadbolt, "Shipwreck May Be Part of Kublai Khan's Lost Fleet," *CNN*, October 27, 2011, https://www.cnn.com/2011/10/25/world/asia/japan-archaeology-shipwreck/index.html.

favored tactics, which relied on cavalry and artillery. Furthermore, the mud slowed French messengers, impeding crucial strategic communications. These factors combined to give the coalition forces the advantage they needed to defeat Napoleon and usher in a new era of European history.

Nearly 130 years later, history repeated itself. Nazi Germany, after reneging on the 1939 Molotov-Ribbentrop Pact, invaded the Soviet Union, initiating "Operation Barbarossa" on June 22, 1941. In the remaining summer months, German forces inflicted heavy casualties upon the Soviets and occupied important economic areas of the USSR, mainly in Ukraine. By early December, Nazi forces reached the outskirts of Moscow, before their winter weather conditions stalled their offensive. The bitter cold prevented the German air force from carrying out large-scale operations, and the German army was not equipped for winter fighting; the cold stopped their equipment from functioning properly. The weather-induced delay gave the Soviets the opportunity they needed to regroup and ultimately push back the Nazi forces in the Battle of Moscow.

Napoleon and many of Hitler's top generals were astute military thinkers and yet, in both cases they significantly underestimated the impact that climate and weather could have on their plans. Hitler's generals had the opportunity to see how climate adversely affected Napoleon's incursion into Russia, and Napoleon should have remembered that, over one hundred years before, in 1708, King Charles XII of Sweden had invaded Russia in the winter to similar futility.

These examples serve to highlight some of history's most significant military scenarios decided by weather and climatic conditions, but they are hardly the only ones. The history of the American Revolutionary War contains numerous instances of both fortuitous and ruinous weather-related events; one notable example being the thick fog that descended over Brooklyn Heights in August of 1776, which obscured Washington's Continental Army from the British and allowed for their safe retreat to Manhattan over the East River, thereby preventing the British Army's siege of Brooklyn. Just a few months later, however, the biting cold and lack of resources during the Continental Army's winter stay in Valley Forge nearly led to catastrophe, as 4,000 soldiers were declared unfit for duty due to resource shortages, and 2,000 soldiers died from malnutrition, disease, and exposure.

In the twenty-first century, weather and climate will continue to shape the international security environment. However, instead of fortuitously timed storms and unusually harsh winters, future challenges will be derived from a climate that is warming at a rate which is unprecedented in human history. The threats posed by anthropogenic climate change will be varied and dynamic, ranging from shifting energy politics in unstable regions of the world to mass migration resulting from drought to the direct threat of rising sea levels that imperils key military infrastructure and capabilities.

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Access to water has been a key factor in the rise of civilizations. Fresh water is essential for human consumption, agriculture, and industrial production, while access to the sea has been an instrumental feature of the growth of empires and international trade.

Today, water has become even more critical to the calculations of nation-states and individual sub-state actors. Rapid population growth is driving an increasing human demand for food and hydropower-generated electricity, and poor infrastructure, resource mismanagement, and scarcity due to geographical and environmental factors make the stresses on many societies even graver. At the same time, climate change is increasing the severity of storms, floods, and droughts, leading to the contamination of freshwater resources, and threatening low-lying regions of the world with storm-surges, coastal flooding, and in some cases disappearance beneath the surf. Thus, an examination of security issues surrounding water—as a resource and as a force of nature threatening human lives and livelihoods—is timely.

Part I of this monograph covers a range of cases in which freshwater scarcity is a key factor in conflicts within societies, as it was in Syria in the run-up to its civil war, and between nation-states, as it is in the Nile River and Indus River basins. Part II focuses on the many ways in which climate change-induced sea level rise will have severe consequences for low-lying coastal regions and island nations throughout the world. The United States is highly vulnerable to new dangers which pose long-term national security risks.