Water Stress and Conflict Severity:

A study on how environmental changes affect conflicts in Africa

Emily Drake

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Acknowledgments

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Abstract

Climate change has been well-established in the academic community, and has been studied for centuries. It is predicted to have many effects on the world, one of them being increases in water stress. Water stress can be seen through shifting precipitation patterns in both directions, shifting access to groundwater or changing groundwater supply, and increased demand, among other factors. This study looks at how precipitation changes have had an impact on conflict severity in countries throughout Africa, as well as how ethnic group distributions, temperature changes, GDP levels, and regional changes affect conflict severity through negative binomial regressions. It looks at conflicts from 1997 to 2014 on the African continent. When conflicts occur during times of negative water stress, the results indicated an increase in conflict severity and supported the hypotheses. When conflicts occur during times of positive water stress, the results differed depending on the region. As water stress worsens and temperatures increase with global warming, conflicts will get more severe, especially for less developed nations with large numbers of ethnic groups.

Introduction

Anthropogenic climate change is anticipated to have consequences that reach beyond just the environment (Homer-Dixon 1994; Tol 2009). Global warming is linked to an enhanced greenhouse effect, which is the result of increased anthropogenic, or man-made, emissions of greenhouse gases, especially carbon. As the average global temperature continues to rise, and the climate becomes more prone to extremes, climate change raises security questions for both developed and developing countries. As early as 1990, a report filed with the United States Naval War College explored the potential security implications of global warming for the United States Navy, expressing concern that “nearly all areas of operational effectiveness are threatened by these environmental changes [of climate change]” (Kelley 1990). Climate change is predicted to cause many environmental shifts, from melting polar ice caps and massive flooding to changing precipitation patterns and megadroughts. As climates continue to change, so will resource distribution, and conflicts may begin to arise (Bernauer, Bohmelt, Koubi 2012; Gleick 1993). Increased water stress is an anticipated result of climate change, and one that has been claimed to have already led to conflict and is predicted to cause more (Hendrix and Salehyan 2012; Homer-Dixon 1994; Raleigh and Urdal 2007).

This study looks at how water stress has had an impact on conflict severity in countries throughout Africa. To do so, it uses the Armed Conflict Location & Event Data Project’s database to study conflicts in Africa. It also uses air temperature and precipitation datasets from the University of Delaware’s Center for Climatic Research, and the World Development Indicators database from the World Bank. Furthermore, the International Groundwater Resources Assessment Centre’s Groundwater Resources in Africa database will be used for climatic and water resource data. This study will attempt to determine what, if any, effect water and temperature stress has on conflict severity, which this study will define as the number of deaths in a conflict. It will study water stress through looking at differing precipitation levels, increased temperatures, and access to alternative water sources. This study will then explore the different factors that contribute to conflict due to water stress, including ethnic distributions, the Gross Domestic Product of the nation where the conflict took place, and regional variations in conflict severity.

First, it will examine the history of climate change research, and what the effects of climate change are expected to be. Next, water stress and trends in water demand will be considered. Then, it will discuss certain risk factors that make areas more vulnerable to the effects of global warming. This study focuses on Africa, and presents a brief case study to demonstrate the connection between water stress and conflict on that continent before presenting the quantitative research.

History of Climate Change Research

Over a century of research has gone into climate science, beginning with work performed by Joseph Fourier in 1824. Fourier introduced the idea that the Earth's temperature was affected by three principal sources of heat: solar radiation, primordial heat diffusing from the core of the planet, and heat from interplanetary space (Fourier 1824). The idea of anthropogenic global warming specifically as a result of enhanced greenhouse gases dates back to 1896, when Svante Arrhenius hypothesized that coal-burning was causing the temperature of the Earth to rise (Arrhenius 1896). His paper is now considered to be the birth of modern climate science. At the time, Arrhenius considered this rising temperature to be a good change, as it would make the overall climate more hospitable and make the northern countries more desirable. His living in Sweden, admittedly, might have had to do with his attitude. In 1938, Guy Callendar showed that carbon dioxide levels were rising along with temperatures, a trend that became known as the "Callendar Effect." Callendar also discussed the Urban Heat Island Effect, by which temperature readings are warmer in cities than in open spaces due to decreased albedo, or reflective power (Albedo 2018; Callendar 1938).

Our current carbon dioxide concentrations show how drastic of an effect global warming has had on our climate. Ice core bubbles have established the historical carbon dioxide concentrations and their correlation to past interglacial and glacial periods. Going back over 160,000 years, carbon dioxide concentrations have vacillated between approximately 180 and 280 parts per million, the former in glacial periods and the latter in interglacial periods. While this seemed low compared to the 345 parts per million concentration in 1938 when Callendar's paper was written, compared to our current 408 parts per million concentration, 280 parts per million seems positively distant (see figure 1) (Barnola et al. 1987; CO2 Earth 2018). This research has continued both privately and through government sources. The

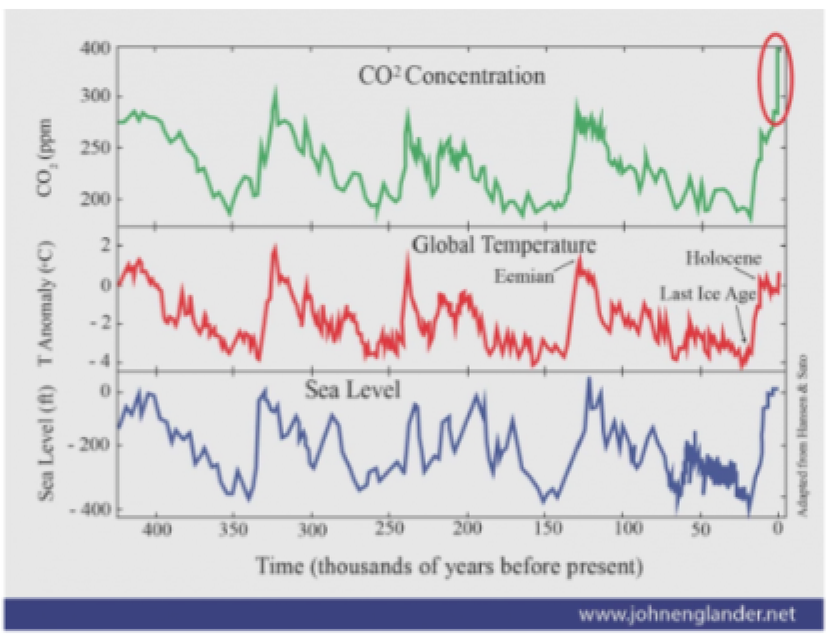

Figure 1: Shows how carbon dioxide concentration, global temperature, and sea level have changed over the past 420,000 years. The way carbon dioxide concentrations have reached new levels in the past few years should be noted. John Englander. 2011. "Chart of 420,000 year history: temperature, CO2, sea level."

Intergovernmental Panel on Climate Change was set up by the United Nations and is dedicated to providing as close to an objective and purely scientific, meaning without political or social influence, view on climate change as possible. In the IPCC's Fifth Assessment Report report, they decreed "human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history" (IPCC 2015, 1).

Among modern academics and climate scientists, there is a consensus that climate change is both anthropogenic in nature and is ongoing. In Naomi Oreskes's study conducted in 2004, out of 928 surveyed academic papers that mention climate change, not a single one disagreed with the existence of climate change. This consensus was further substantiated in 2013, when Evan Lehmann's survey of over one thousand scientists resulted in 97% of those respondents agreeing that climate change was real and that humans were the cause. In J.S. Carlton's 2015 study, the few scientists who did not agree with climate change had disagreements over basic facts, such as the effects of carbon dioxide on the climate. These scientists were, unsurprisingly, found to have different cultural and political values from the supporters of anthropogenic climate change. It was also determined that the more participants used mass media as opposed to scientific literature to obtain information on climate change, the less likely they were to be certain of the existence of anthropogenic climate change. Essentially, what all this means is that within the scientific community, there is a clear consensus on climate change; it is real, and it is man-made.

Effects of Climate Change

Perhaps the most well-known consequence of global warming is, as one might expect, increasing temperatures. In 2012, a study by James Hansen found that there was a significantly increasing amount of unusually high temperatures in the past three decades (see figure 2). There has been a large increase, greater than an order of magnitude, in the size of the category of extremely hot summers, or summers in which the mean temperature is over three standard deviations greater than average. Essentially, this means that summers are getting much, much hotter than they have been in the past. Furthermore, this rapid increase in temperature is not just happening in one place; rather, there are entire regions of the world seeing this sharp uptick. While local extreme warming is not a new phenomenon, these large, spread out areas of extreme warming are. Temperature deviations also have many secondary effects beyond just the hotter weather, and are one of the contributing factors to water stress (Lobell, Schlenker, Costa-Roberts 2011; Walther 2002; Wheeler and von Braun 2013).

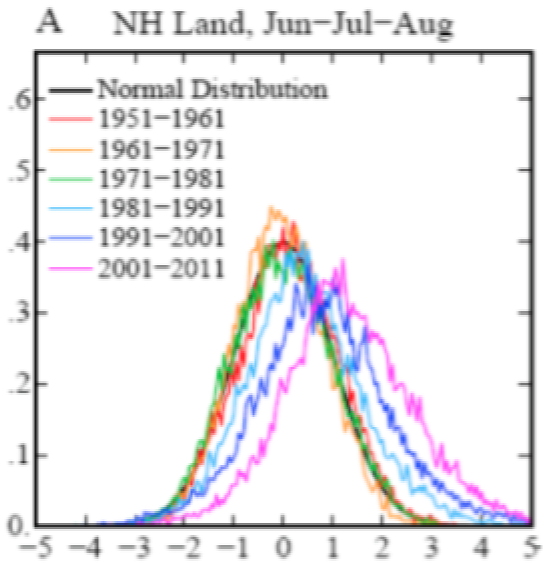

Figure 2: Shows the changing temperature distribution of summers. The distribution is increasing significantly.
Hansen et. al. 2012. "Extreme Metrics."

Climate change is anticipated to have many effects, including rising sea levels, ocean acidification, desertification, soil degradation, increased wildfires, and increased storm frequency, severity, and duration to name just a few (NASA 2017b). These changes are not isolated, and actually can all be interrelated; as temperatures increase, droughts can be more likely to occur, causing soil degradation and a subsequent loss of agricultural land (Homer-Dixon 1994). Some of these effects could cause resource shortage-based conflict without even being related to climate change, including the degradation and loss of agricultural land and forests, the depletion and pollution of fresh water supplies, and the depletion of fisheries (Homer-Dixon

1994). It is important to note that not all climate and ecological problems are because of anthropogenic climate change; in fact, these aforementioned problems already existed, and some actually contribute to climate change. Climate change will just simply make these problems worse.

Water stress is expected to increase as the world continues to warm, partially through the continued depletion and pollution of freshwater and decreases in water quality, though this will not affect all countries and regions equally (Vorosmarty et al. 2000; Whitehead et al. 2009). Certain areas are anticipated to suffer more severely from a lack of usable water than others. Called colloquially the “wet-get-wetter, dry-get-drier” paradigm, a theory advanced by Held and Solden’s 2006 paper states that areas which are predisposed to drought will become more and more dry, whereas areas that traditionally have greater precipitation will become more likely to flood. Simply put, extremes will become more extreme (Putnam and Broecker 2017). The Middle East, sub-Saharan Africa, and Southeast Asia, for example, are all predicted to experience increased water stress due to decreased precipitation more generally than other parts of the world, though each region in different ways (World Resources Institute 2018a). Other parts of the world, including East Africa, are going to experience increased water stress due to drastic increases in precipitation rates. This is especially true for areas that already experience oversaturation of water during wet seasons. In many of these areas there are other social, political, and economic problems plaguing them already, which could exacerbate the problems posed by water stress.

Water Stress

Defining water stress can be a complicated task, and there already are many different definitions. Water stress can be defined as extreme deviations in either direction away from the mean in terms of water accessibility and precipitation, as well as a degradation in water quality. The United Nations defines a country as reaching critical water stress levels when there is less than 1500 cubic meters of potable freshwater per person annually (Brozek 2013). Another way to look at water stress is to look at how much water availability varies from dry years to mean values, and look at how extreme values vary between regions. One could also compare the average annual runoff, or the amount that is discharged from the area, to the withdrawal rate, and look at the amount of water available per person (Arnel 2004; USGS 2018). Furthermore, it is not clear how exactly warming will affect precipitation and water resource systems (Taylor, Koussis, and Tindimugaya 2009). In other words, water stress can be experienced as a result of too much water as well as too little, and can be caused not only because of differing amounts of rain, but also because of problems with the water once it reaches the ground. Most of these definitions, however, arise from an intent to treat water stress as a categorical or dichotomous variable that you either are or are not. For this study, water stress will not be treated as a dichotomy, but rather it will be evaluated as a scale with multiple contributing factors.

One factor that contributes to water stress is the distribution of freshwater. While water is considered a renewable resource, freshwater is only a small fraction of the world's water resources and is oftentimes poorly distributed (Brozek 2013). The distribution issue is caused by a variety of problems, including political and environmental ones. Politically speaking, reliable access to water is crucial for political and social development, but water does not obey political boundaries. Oftentimes water resources are under the control of one nation or group to the detriment of others (Gleick 1993). As a result, political actors that use transboundary water resources have the opportunity to interfere with other actors' access. While according to international law transboundary water sources should be shared equitably and reasonably, a collective action problem exists; each actor has the temptation to use the water without concern for others or for long term sustainability (Brozek 2013; International Law Commission 2008; Saeijs and van Berkel 1995). This means that because water sources are not limited to one country or one group of people, each actor has an incentive to use the supply before anyone else does.

Environmentally speaking, there are a number of factors that contribute to water stress. Freshwater comes from two different types of sources: surface water, or blue water, and groundwater, also known as brown water (USGS Water Science School 2017). Looking first at blue water, precipitation is one of the ways surface water is produced, and is defined as a deposit on the earth of rain, sleet, mist, snow, or hail. Precipitation can have a lot of natural variation both geographically and over time (Theisen, Holtermann, and Buhaug 2012). One way water stress can occur is because of precipitation extremes on both ends of the spectrum - increases in precipitation can cause damage as well as decreases, as well as issues with water quality. As previously discussed, some areas get too much water, while others do not get nearly enough. Annually, climate change is predicted to cause even greater precipitation variations of 10-25%, while monthly the extremes would be even larger (Arnel 2004; Gleick 1993). Increases can especially cause stress in traditionally wet seasons when the extra water is unavailable during the dry season and instead hits an oversaturated area (Arnel 2004). In the event of too much water, there can be flooding, mudslides, increased disease, and crop damage. When there is too little precipitation, there can be drought, potential crop failure, and reduced water availability (Hendrix and Salehyan 2012). For the purposes of this study, "positive" water stress will describe when there is more precipitation than average, and "negative" water stress will describe when there is less precipitation than average.

Issues with groundwater also can contribute to water stress. Groundwater is water stored in the ground in aquifers. Groundwater is more steady and resilient to weather and climate variations because of its slow movement, especially when the supply is not impacted by precipitation (Taylor, Koussis, and Tindimugaya 2009). It is the largest accessible store of reliable freshwater for most people, especially when river discharges and precipitation patterns are variable or particularly low. This kind of resource is usually potable, and can sustain communities when surface waters are not as constant (Taylor, Koussis, and Tindimugaya 2009). Aquifers, however, can be harder to access than surface water. Coastal aquifers and surface water sources especially are vulnerable not only to changing precipitation patterns, but also to a degradation in their water quality as a result of sea level rise increasing saltwater concentrations (Taylor, Koussis, and Tindimugaya 2009).

Water stress can be caused by issues with water quality, as well as water quantity. With increased pollution or other water quality degradation, there does not necessarily need to be changes in the precipitation pattern for there to be a change in the level of water stress. As sea levels increase, countries with non-renewable aquifers (aquifers that are not rainfed and do not receive surface runoff) and countries which take more water out of renewable aquifers than is put in will be more vulnerable to water quality degradation. When an aquifer is pumped below its water table, which is essentially its stability point, it draws on water from its environment in order to boost its levels to match the water table, no matter the quality of the exterior water. As a result, when an aquifer is over pumped, it can draw in lower quality water from its surroundings and increase the saline concentration of the aquifer among other contaminant concentrations (Al-Ibrahim 1991). This means that in times when precipitation is particularly low, water stress can come both from a lack of surface water and a subsequent degradation in groundwater quality.

Essentially, there are many factors to consider in determining water stress. Increased water stress due to climate change can be the result of many factors, including shifting precipitation patterns, extreme weather events, overuse of aquifers, faulty water infrastructure, poor or variable economic development, greater use of the water supply, increased pollution, and exacerbation of politically unclear and volatile claims to water sources. As temperatures rise, so will evaporation rates as well as water demands. Even without changes in precipitation, water availability can decrease by 10% or more just from small rises in temperature (Gleick 1993, 96). These changes can affect both brown water and blue water, and to ignore one leaves out a crucial part of the community's water access. Whether a community has access to clean groundwater through an aquifer should be considered a factor in determining if they are undergoing water stress, though it is harder to get an accurate assessment of groundwater sources. Overall, there may be plenty of freshwater on (and in) the planet for the world's population, but ensuring that it is safe to drink, accessible, storable, and able to be moved from where it is to where it needs to be is far from a simple task (Brozek 2013; Schiefler 2017). By 2030, between 374 and 1661 million people are predicted to experience an increase in water stress (Arnel 2004). People do not just need any water, they need water that is safe, accessible, and drinkable.

Risk Factors

Certain economic and geographical factors put countries at more of a risk of climate change, especially water stress. Economically, less-developed countries will face more extreme impacts due to a lack of resources which otherwise could help mitigate the effects of water stress (Gentle et al. 2014). This means that even if a more-developed country were to experience the same environmental event as a less-developed one, they would be better equipped to deal with both prevention and recovery than the less-developed nation. There is not a clear divide between less-developed and more-developed countries' water usage levels; for example, both the United States and Niger have a total water footprint of over 3000 cubic meters per person annually (Hoekstra and Mekonnen 2012). The Democratic Republic of Congo and China both meanwhile have some of the lowest water usage levels of less than 1000 cubic meters per person annually for China and under 750 for the DRC (Hoekstra and Mekonnen 2012). Thus, while some countries may require more water and subsequently be more vulnerable, there is not a definitive link between a country's water usage and their economic status.

A country's gross domestic product is one of the most important factors in determining its response to climate change. Research shows that wealth decreases the probability of violent conflict, and that recessions increase the risk of conflict (Humphreys 2003). This could be because less-developed countries are more inclined to experience negative effects from resource shortages as they do not have the capabilities or resources, or oftentimes the knowledge, to overcome and mitigate them (Theisen 2012). Less-developed and low-income countries are predicted to suffer a loss of a greater economic percentage of their GDP, although the more-developed world will lose overall more money (see figure 3). As a result, overall inequality

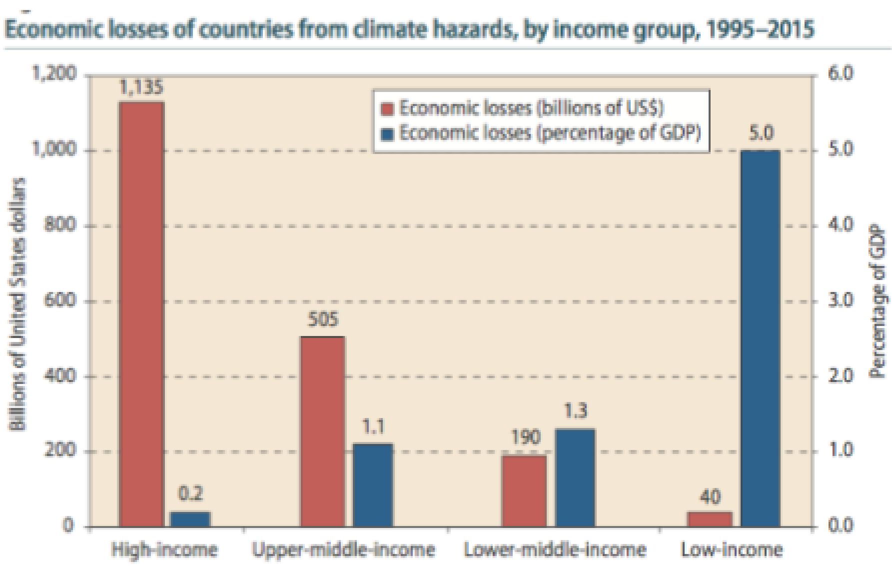

Figure 3: demonstrates the losses from climate hazards to different income groups, both in billions of dollars and percentage of their individual GDPs. World Economic and Social Survey. 2016. "Economic Losses."

will be further exacerbated between countries (United Nations 2016). Countries with lower GDPs per capita also have more poverty, which leads to emigration and conflict over limited resources between differing groups (Humphreys 2003). They do not have the luxury of being able to put money and time into planning for long-term prevention, and thus must instead do their best to mitigate the damage when it comes.

There is high potential for dispute when water stress impacts a marginalized population. The population will be unable to make alternative modes of living due to lack of resources, and are more likely to be ignored by the government (Theisen 2012). Water stress and other impacts from climate change lead the at-risk population into a cycle: the inherent inequalities lead to greater risk and exposure for the marginalized group to the environmental changes, which leads to a disproportionate loss of lives and income for the marginalized group, exacerbating the inherent inequalities and continuing the cycle (United Nations 2016). These disadvantaged groups generally have fewer options for diversifying their livelihoods, and thus are unable to adapt as quickly or as easily to changing climates. Furthermore, these disadvantaged groups typically operate in the most at-risk environments, both physically being more exposed to natural disasters including mudslides, wind storms, and droughts, and economically being more exposed with more expendable occupations and tenuous livelihoods. In a study done in Nepal, for example, it was found that lower-income houses suffered on average 2.63 environmental hazards over a six-year period, while well-off households suffered only 1.76 on average over the same time scale (Gentle et al. 2014).

Certain areas are going to be more vulnerable to different effects of climate change and water stress. Island, coastal, low-lying, and equatorial nations are all more likely to be at risk of sea-level rise and resulting water quality degradation (IPCC 2001). By 2100, most projections conservatively estimate that sea level will rise between 0.2 and 2 meters, with the two greatest sources of that rise coming from thermal expansion of seawater and melting land ice (NASA n.d.). Sea levels have been steadily rising with a current rate of change of 3.4 millimeters per year (see figure 4). If the Greenland Ice Sheet, which contains 9% of the world's land ice, were to melt, sea levels would rise another 23 feet (Gregory, Huybrechts, and Raper 2004). Antarctica, meanwhile, which holds 90% of the world's land ice, has enough ice to raise sea levels by another 200 feet.

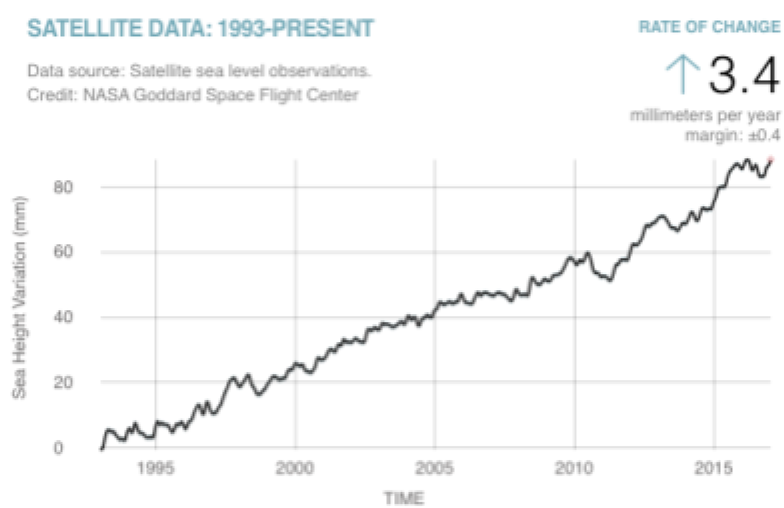

Figure 4 NASA. "Sea Level". Last Modified April 16, 2017. https://climate.nasa.gov/vital-signs/sea-level/

Antarctica is losing ice more slowly than Greenland, but the latest data estimated it is still losing about 92 billion tons of ice per year (Lythe and Vaughan 2001). Sea level rise poses a risk not only for the loss of land area, but also for the resulting salinity increase in water sources.

Africa as a Research Focus

This study focuses on Africa. Africa is just over 30 million square kilometers, and contains a wide variety of climates and environments. Its climates include humid equatorial, seasonally humid, semi-arid, arid, and sub-tropical Mediterranean, while its biomes include scrub land and savannah environments, lowland and montane forests, and deserts (IPCC 2007; Taylor, Koussis, and Tindimugaya 2009). Partially because of this diversity, effects of climate change across Africa are not going to be uniform. 54 countries belong to both the African Union and the United Nations, though the count can vary significantly depending on which countries are recognized and one's political stance (Brown, Hammill, Mcleman 2007, 1143; United Nations 2017). There are 113 transboundary water sources in Africa, and about 60% of Africa's territory falls into a transboundary watershed. Every state in Africa uses water from at least one transboundary water source making it the most hydrologically interdependent region on the planet (Brozek 2013).

Africa was selected as the nexus of this study as the effects of climate change are anticipated to be seen sooner and more intensely in Africa than the rest of the world (Brown, Hammill, and Mcleman 2007; Taylor, Koussis, and Tindimugaya 2009). The projected warming across the continent is predicted to be 1.5 times the global mean (Taylor, Koussis, and Tindimugaya 2009). Africa is anticipated to experience an increase in frequency and severity of floods, droughts, and storms, especially in coastal areas (see figures 5 through 7) (Aqueduct

Water Risk Atlas 2017; Brown, Hammill, Mcleman 2007). Thanks to increases in both intense rainfall events and sea level rise, flooding events are predicted to become more frequent, with areas like the Nile Delta, being both densely populated and low-lying, becoming extremely vulnerable to sea level rise. Erratic rainfall, longer dry periods, and more intense rainfall events are expected to place pressure on African agriculture and economies (Hendrix and Salehyan 2012). Africa's agricultural sector especially is predicted to be affected by water stress due to climate change; by 2020, between 75 and 250 million people on the continent are expected to be under increased water stress, resulting in some countries' yields being reduced by up to 50%. Sub-Saharan Africa and southeast Asia may have already begun experiencing decreased land productivity as a result of water stress (United Nations 2016).

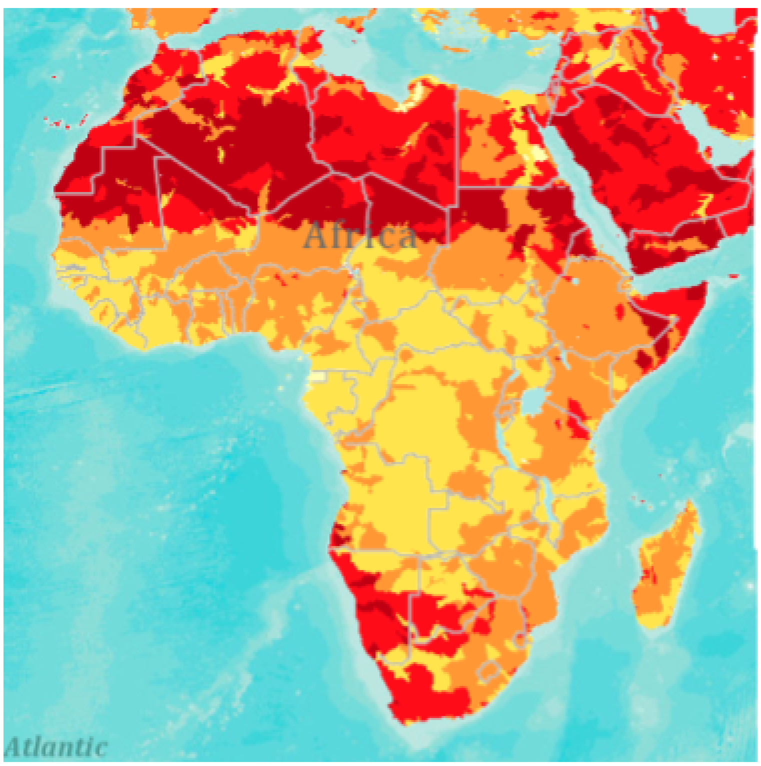

Figure 5: Shows the water stress levels currently of Africa. Pale yellow shows low risk, dark red shows extremely high risk.
Aqueduct Water Risk Atlas. 2017. "Map of Water Stress Area, Current Conditions."

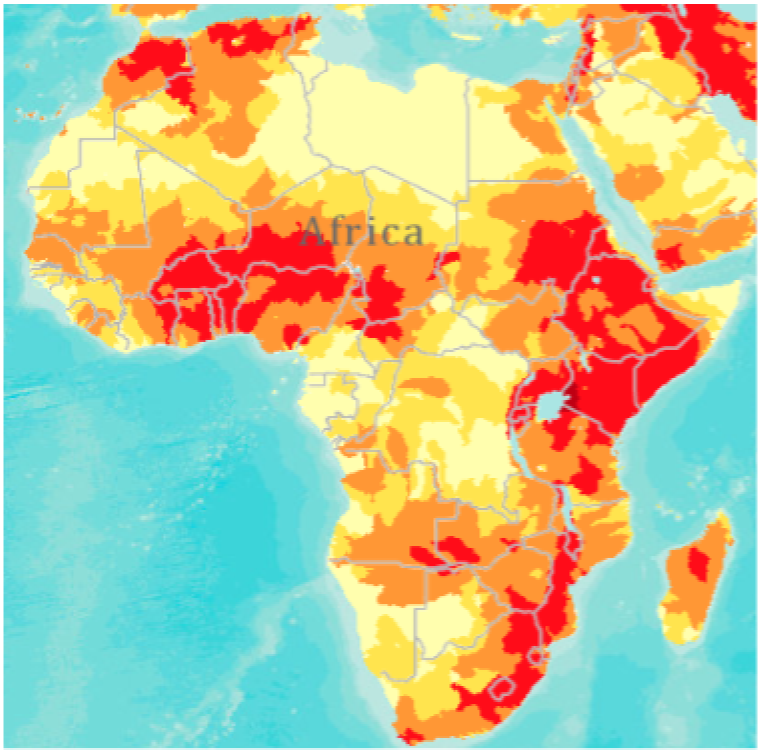

Figure 6: Shows the flood occurrence in Africa based on the number of floods from 1985 to 2011. Dark red shows extremely high occurrence, pale yellow low occurence
Aqueduct Water Risk Atlas. 2017. "Flood occurrence."

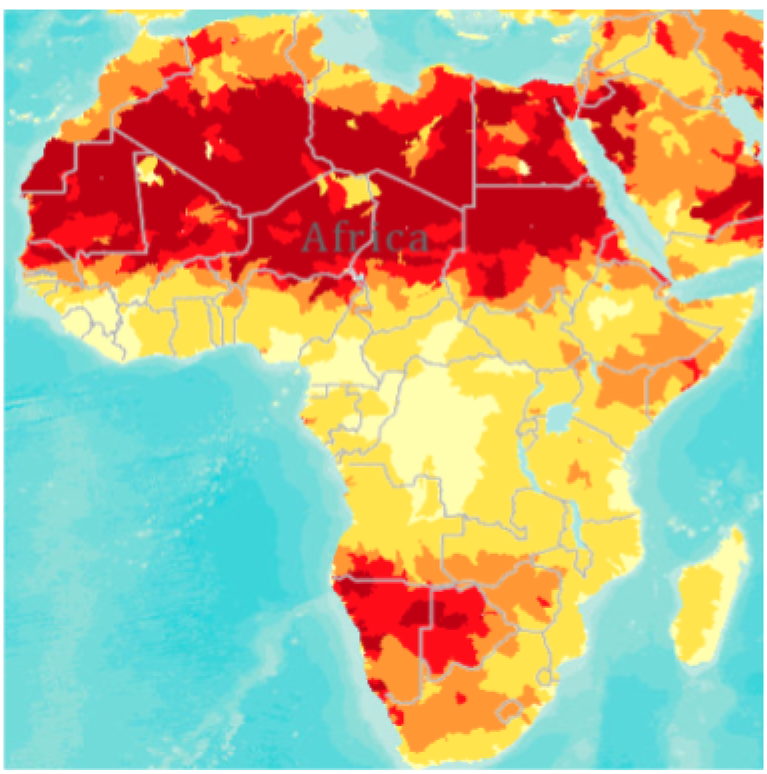

Figure 7: Shows the drought severity for Africa based on the average length of droughts times the severity of the droughts from 1901 to 2008. Dark red shows extremely high severity, pale yellow shows low severity.
Aqueduct Water Risk Atlas. 2017. "Current Drought Severity."

Africa also has a wide variety of social, political, and ethnic groups. Over 70% of the population in sub-Saharan Africa lacks basic civil rights and liberties, qualifying as a marginalized group. Strong ethnic divides are present in nearly every state; in Nigeria, for example, there are approximately 160 different ethnic groups, while there are as many as 2000 different languages spoken on the continent as a whole (Hitchcock 1993). This large number of different ethnic groups could contribute to conflict severity. Partially as a result of Africa's history with colonialism, many of the political borders cut through natural borders and divides, resulting in more transboundary water sources. This also contributes to the degradation of historical tribal governments, resulting in a high diversity of political types and strengths (Brozek 2013).

There are problems with the data available on Africa. While understanding the importance and demand of groundwater resources and systems in Africa is crucial to understanding the effects of water stress, a common characteristic of all African hydrological systems is a lack of sustained time series data as well as a lack of observations overall. Taylor et al. (2009) discusses how the water resources available in Africa are not well-established, and there is high variability in the rainfall in Africa. As a result, 95% of the annual rainfall totals deviate 20-40% from the mean. There is significant variance in precipitation and subsequent river discharge both from year to year and from season to season. Total withdrawals could range from 4050 cubic kilometers per year to 4590 cubic kilometers per year, but the significance of that amount depends on both the amount of precipitation fallen and the pattern at which it fell. A portion of the freshwater resources occur as groundwater in aquifers, not as precipitation, though estimates range for this amount being anywhere from 15%

to over 50%. As a result, looking only at precipitation levels does not take into account what could be a large portion of the continent's water resources. These aquifer estimates are supported by very few data points, however, and only consider a very small proportion of renewable resources. Groundwater is relied upon as the primary source of drinking water by approximately 50-75% of the African population, meaning any study that looks at water stress in Africa needs to consider groundwater as well as surface water in its assessment.

Darfur -- A Case Study

Darfur has become one of the most frequently cited examples of modern climate conflict. This analysis of this case illustrates how climate change can lead to conflict. One view of the region is that the drought in the 1980s led to conflict through a multi-year famine that exacerbated pre-existing ethnic divides. These studies contend that the drought caused by climate change began a domino effect that took 30 years to reach fruition. The drought led to a famine, which caused a heightening of tribal rivalries over grazing land and water (Mazo 2010). On the other hand, some find that the link between the drought and the onset of the conflict to be far too tenuous. Kevane and Gray (2008) determined that the connection between low precipitation rates and the conflict could not be drawn as the precipitation dropped 30 years before the conflict began.

Sub-Saharan Africa, and Sudan in particular, is very vulnerable to water stress. The United Nations Environmental Program (2005) reported that since Sudan's independence in 1956, nearly three-quarters of the violent local conflicts in the area have involved grazing and water rights. One-third of the African population as a whole lives in drought-prone areas, and almost all of sub-Saharan Africa is predicted to be in water stress areas by 2025 (Theisen 2012).

Right now, in sub-Saharan Africa over 340 million people lack access to potable water, and only 4% of annual renewable water flows are stored. For context, about 70 to 90% of annual renewable water flows are stored on average in the developed world (Hendrix and Salehyan 2012). The northern area of Darfur is a desert, the central part a plateau, and the southern part a tundra that usually experiences plentiful precipitation. The primary source of income in Darfur is rainfed crop cultivation. Regions where agriculture is currently a marginal enterprise, largely due to a combination of poor soils, water scarcity, and rural poverty, suffer increasingly as a result of climate change impacts on water (Kevane and Gray 2008). As a result, even small changes in climate will increase the number of people at risk of hunger, with the impact being particularly great in sub-Saharan Africa, including Sudan.

The conflict in Darfur has been ongoing. The current war began in 2003 and has since devolved into a genocide. Since its independence in 1956, political instability and civil war has marred Sudan. From 1980 to 1984, Darfur was in a prolonged drought. Throughout the 1980s and 1990s, this drought worked in combination with desertification and increased population growth to produce a steep decline in food production and a subsequent rise in famine. Sedentary farmers and pastoralists soon began to clash over resources as supplies dwindled (Kevane and Gray 2008). As pastoral nomads moved south from the desert following the traditional arrangements agreed upon years prior, with the changing climate and unpredictable harvests, sedentary farmers found themselves competing more with the nomads over more and more limited resources. With the degradation of the traditional tribal system brought on by colonialism and the government, tribal leaders had less control over their people and were unable to mediate conflicts, meaning that even as they got worse, there were fewer mitigation strategies available to deal with them (Sikainga 2009).

The conflict in Darfur subsequently began to be called a climate conflict. In June 2007, United Nations Secretary-General Ban Ki-moon (2007) declared that anthropogenic climate change was a major contributing factor to the Darfur conflict. Before that, while the idea of Darfur being a climate conflict had been discussed, it had only been publically been declared to be one by environmentalists such as Al Gore (Kevane and Gray 2008). To declare the genocide in Darfur to be solely a climate conflict would be a specious leap at best; there were many other ethnic and political tensions at work, and the drought and subsequent famine acted more as a spark on an already-built tinderbox. Climate change surely did play a role in beginning the events in Darfur, but it certainly was not the only factor at play. Calls to name Darfur as the first definitive instance of acute climate conflict are oftentimes overinflated and politicized; by making climate change a life-threatening and urgent security threat, it can go from being a liberal environmental issue to a national security one. Still, climate change did act as a threat-multiplier in Darfur, giving rise to conflict where one might not have occurred before or, at least, it sped up the process. Thus, while Darfur may not have been a case of acute climate conflict, climate change-induced water stress had a role in setting the stage for the conflict.

Literature on Water Stress and Conflict

The field of climate conflict research is relatively young, and existing research on the connection between water stress and conflict is conflicted. Within the hypothesis that water stress leads to an increase in conflict there are a number of suggested explanatory mechanisms. One common mechanism to explain this is a simple scarcity model in which water shortages leads to resource scarcity, which subsequently causes increases in competition (Bernauer, Bohmelt, Koubi 2012; Brown, Hammill, Mcleman 2007; Hendrix and Salehyan 2012; Homer-Dixon 1994; Mazo 2010; Yoffe et al. 2004). Environmental scarcities, such as water shortages, can have three different types of causes: supply-induced scarcity, in which the resource availability is decreased due to degradation or usage rates greater than the regeneration rates, demand-induced scarcity, such as increased consumption because of growing population growth rates, and structural scarcity caused by distribution issues (Bernauer, Bohmelt, Koubi 2012). This increased competition makes conflict more likely. This especially applies to shortages that involve basic needs, such as, in this case, water shortages. There has been some evidence to support the idea, however, that increased water access actually contributes to conflict. In this case, actors will not launch campaigns when there is not enough access to water to supply the combatants during the conflict (Hendrix and Salehyan, 2012).

A second mechanism to explain the connection between water stress and conflict severity is through conflicts over group identity caused by migration due to resource shortages (Bernauer, Bohmelt, Koubi 2012; Raleigh et al. 2008; Raleigh 2010; Sandler 2004). Undue water stress, caused by either too much or too little water, could cause resource shortages. These shortages could be either the water itself in the event of too little water, or could be something else, such as a food shortage as a result of floods and agricultural field destruction. The group who relies on the resource experiencing the shortage would then move to find other resources, and conflict between the pre-existing population and the immigrating population could occur. Ethnic divides or disputes could increase the severity of conflict (Theisen, Holtermann, and Buhaug 2012). Already having an "us-against-them" mentality allows for easier dehumanization of the enemy and for each group to feel they have justice on their side, increasing the likelihood of armed conflict. Otherwise, new factions must be formed with new power structures and organizations. Furthermore, the conflict, rather than being about the absolute level of resources, is more about the distribution of the resources (Bernauer, Bohmelt, Koubi 2012; Hendrix and Salehyan 2012; Homer-Dixon 1994). Limited resources then become both a source of conflict and a further weapon to be used in ethnic or political conflict.

As agricultural conditions shift, workers may begin to move away from hard-hit areas, exacerbating pre-existing economic problems or creating new ones with a decreasing labor force in the area where they originated and causing increased competition for resources where they go. Traditional cycles of planting and harvest will likely be interrupted or changed altogether as precipitation patterns change (Hendrix 2012). It is important to remember agriculture, for better or worse, is affected by many factors other than just climate; the agricultural methods used and the tools available to the farmers can have a much more significant effect on how successful a farm is than the climate (Howden 2007). They can also impact the likelihood of a country's success in adapting to new environments; these methods, though, typically require significant investment not available to most developing nations. Thus, a country's economic welfare can also affect the likelihood of water stress contributing to conflict severity.

A third mechanism for the connection of water stress and conflict explains that the resource shortage could cause a decrease in economic welfare of the state and subsequently disrupt the government and critical social institutions. Because of environmental shortages, economic deprivation occurs which leads to civil strife. These shortages also lead to increased financial and political pressure on the state, and creates more groups dependent on the state for support and survival. In weaker states, this pressure can leave the government vulnerable. Thus, civil war and insurgency would be more likely to occur (Homer-Dixon 1994; Wischnath and Buhaug 2014). This vulnerability to resource degradation is especially prevalent in poorer countries and countries that depend on natural resources (Brown, Hammill, and Mcleman 2007; Homer-Dixon 1994).

Another explanation applies to transboundary water resources in that these resources pose a collective action problem. River water specifically is expected to be the most likely renewable resource at the source of conflict in the future (Homer-Dixon 1994). As a result, as these resources become more scarce and thus more valuable, the parties that depend on these resources are more willing to pursue guaranteed access in the face of greater costs and risks of military fighting (Brozek 2013). Thus, having a shared aquifer could exacerbate conflicts. Another explanation given is that an abundance of natural resources can lead to political violence, again especially over distribution. These kinds of conflicts, however, tend to be focused over more nonrenewable, valuable resources rather than necessities (Hendrix, Salehyan 2012).

Finally, a commonly accepted explanation for the connection between climate change and conflict is that climate change is a 'threat multiplier', and exacerbates pre-existing conditions rather than causing the conflict in and of itself, as climate conflict is often understood (CNA Corporation, 2007; Theisen, Holtermann, and Buhaug 2012). Armed conflict does not produce more natural resources, and instead may use even more of the limited supply (Hendrix 2012, Brozek 2013). Water stress merely increases pre-existing divides and fractures, making other conflicts more severe. Therefore, the fact that areas in the past had experienced conflict or had issues that ordinarily would not warrant conflict would make them more likely to then experience severe conflict when water stress is added.

There were a number of factors found to, or predicted to, have an impact on conflict frequency and severity, including discrimination and political marginalization of ethnic groups and poor economic performance (Fearon and Laitin 2003; Theisen, Holtermann, and Buhaug 2012). The Transboundary Freshwater Conflict Severity Index, in order to determine the level of conflict associated with different water basins, looked at aquifers as an index (Brozek 2013). This inclusion of aquifer resources would improve the estimate of water stress drastically. In order to try to account for these aforementioned variances, the GDP per country will be included in the model, as well the presence of aquifers, and the number of ethnic groups in the area.

Empirical Research

Most studies looked merely at the incidence of conflict or the frequency of conflict, rather than the severity (Burke et al. 2009; Hendrix and Salehyan 2007; Hendrix and Salehyan 2012; Irby 2017; O'Laughlin et al. 2012; Raleigh and Urdal 2007; Wolf 1998). Conflict severity is thus less well-studied. This study examines the impact water stress has on conflict severity. It defines conflict severity, the dependent variable, through the number of total fatalities in each conflict. This study only examines conflicts, including conflicts with zero fatalities, and it looks exclusively at conflict severity rather than probability of conflict occurrence. All three mechanisms described above are plausible, so this study will examine each. The scarcity model will be examined through looking purely at temperature and precipitation data, as well as whether or not the area has alternative forms of water sources in the form of aquifers. The group identity model will be examined through the temperature and precipitation data, as well as whether or not there are multiple ethnic groups in the area. Finally, the economic welfare model will be examined through temperature and precipitation data combined with the GDP of the countries. This study will also examine whether or not a combination of these different mechanisms increases conflict severity.

This study looks at conflicts in Africa from 1997 to 2014. The dependent variable is the number of fatalities in a conflict. A conflict will be defined using the Armed Conflict Location & Event Data Project's definition, defined as the use of force, or a precursor to the use of force, by a group with political intentions through the analysis of subsequent events (ACLED 2018).[1] The independent variables are temperature and precipitation deviation, the number of ethnicities within 10 miles of the conflict, the GDP of the country in which the conflict takes place, and whether or not the conflict is within 2.5 miles of a transboundary aquifer. Whether or not there are any regional effects is examined as well.

For each conflict, the temperature and precipitation data is taken for that month and location from the University of Delaware's Terrestrial Precipitation and Air Temperature databases. The data are then compared to precipitation and temperature data for that month and location using the standard deviation and mean of these variables from 1950 to 1996. Temperature and precipitation stress are measured by standard deviations from the mean. The Geo-Referencing of Ethnic Groups Database was used to determine how many ethnic groups

[1] ACLED studies conflicts through political disorder and violence, and defines it as "the use of force by a group with a political purpose or motivation. ACLED defines political violence through its constituent events, the intent of which is to produce a comprehensive overview of all forms of political conflict within and across states. A politically violent event is a single altercation where force is often used by one or more groups to a political end, although some instances – including protests and non- violent activity – are included in the dataset to capture the potential pre-cursors or critical junctures in a period of disorder." (ACLED 2018, 1). There are ten event categories included in ACLED, four of which are nonviolent. The first three are different types of battles, then violence against civilians, remote violence, riots (violent demonstrations), and protests (non-violent demonstrations). The three other main forms of non-violent activity ACLED includes are non-violent takeover of territory, headquarter and base establishment, and strategic developments such as looting and high-profile arrests (ACLED 2018).

were within 10 miles of the conflict, and the World Bank's World Development Indicators Database was used to find the annual country GDP for each conflict. Finally, the International Groundwater Resources Assessment Council's Database on Freshwater Resources in Africa was used to determine whether or not the conflicts occurred within 2.5 miles of a transboundary aquifer in order to estimate the effect of shared water sources on conflict. The dependent variable, number of fatalities, was taken from the Armed Conflict Location and Event Data Project, as well as the regional designation of each country and the location of the conflict.[2]

Unlike Wischnath and Buhaug's 2014 paper, which uses Ordinarily Least Squares, a binomial regression is used to determine what, if any, relationship the independent variables have with conflict severity. This is a good way of estimating equations when the dependent variable is a count that never takes on negative values. Positive water stress and negative water stress events will be examined separately to determine if their effects are asymmetric.

Hypotheses

Thus, there are several hypotheses taken from the extant literature that are being tested.

H_0: As positive water stress increases, so will conflict severity.

H_1: As negative water stress increases, so will conflict severity.

H_2: As GDP increases, conflict severity will decrease.

H_3: As the number of ethnicities in the area increases, so will conflict severity.

H_4: The presence of a shared water source will increase conflict severity.

H_5: As positive temperature deviations increases, so will conflict severity.

[2] ACLED's regional designations for the different countries are used for this study. Thus, there are other regionalizations possible, and this study is sensitive to that. No matter where the regional lines are drawn, certain areas will be expected to have outliers, such as any region in which the Democratic Republic of the Congo is included due to its abnormally high fatality levels.

Results

Table 1: General Statistics for Fatalities in Positive Water Stress Cases

Region	**Mean**	**N**	**Standard Deviation**
Northern Africa	4.8532	6347	23.47627
Western Africa	2.6917	7471	20.93095
Middle Africa	17.4769	7024	112.58268
Eastern Africa	3.6014	12048	16.83702
Southern Africa	0.1926	3453	0.97520
Total	*5.9909*	*36343*	*52.56222*

Table 2: General Statistics for Fatalities in Negative Water Stress

Region	**Mean**	**N**	**Standard Deviation**
Northern Africa	4.3792	14252	27.14666
Western Africa	3.2333	10485	16.76975
Middle Africa	8.9342	8795	65.87061
Eastern Africa	7.6832	23148	79.20405
Southern Africa	0.1780	8646	1.02739
Total	*5.4232*	*65326*	*54.80431*

Table 3: Output for Negative Binomial Regression for Negative Water Stress

Parameter	**B**	**Standard Error**	**Wald Chi-Square**	**Sig**
(Intercept)	11.063	.1138	9455.584	.000
[NorthernAfrica=.00]	-3.110	.0385	6525.051	.000
[WesternAfrica=.00]	-2.689	.0395	4630.942	.000
[MiddleAfrica=.00]	-4.099	.0390	11054.734	.000
[EasternAfrica=.00]	-3.471	.0377	8485.847	.000
[SouthernAfrica=.00]	0	-	-	-
[Aquifer=0]	-.153	.0117	169.902	.000
GDP	-1.121E-12	3.9087E-14	823.101	.000
Ethnicities	.348	.0083	1757.348	.000
PositiveTemperature	.131	.0043	907.742	.000
NegativeWater	.115	.0068	289.761	.000

Table 4: Output for Negative Binomial Regression for Positive Water Stress

Parameter	**B**	**Standard Error**	**Wald Chi-Square**	**Sig**
(Intercept)	14.631	1.8417	63.112	.000
[NorthernAfrica=.00]	-4.481	.6521	47.229	.000
[WesternAfrica=.00]	-2.650	.6537	16.433	.000
[MiddleAfrica=.00]	-4.531	.6690	45.875	.000
[EasternAfrica=.00]	-2.734	.6114	19.997	.000
[SouthernAfrica=.00]	0	-	-	-
[Aquifer=0]	-.296	.3258	.825	.364
GDP	-1.235E-12	1.0270E-12	1.446	.229
Ethnicities	.247	.1749	2.001	.157
PositiveTemperature	-.022	.0345	.400	.527
PositiveWater	.008	.0081	.941	.332

Table 5: Output for Negative Binomial Regression for Positive Water Stress in Middle Africa

Parameter	B	Standard Error	Wald Chi-Square	Sig
(Intercept)	1.567	.0450	1211.849	.000
[Aquifer=0]	.284	.0315	81.053	.000
GDP	9.108E-15	1.5559E-13	.003	.953
Ethnicities	-.133	.0152	75.964	.000
PositiveTemperature	.031	.056	18.681	.000
PositiveWater	.056	.0031	100.639	.000

Table 6: Output for Negative Binomial Regression for Positive Water Stress in Eastern, Northern, Western, and Southern Africa Water Stress

Parameter	B	Standard Error	Wald Chi-Square	Sig
(Intercept)	1.210	.0234	2675.616	.000
[Aquifer=0]	-.447	.0176	642.770	.000
GDP	-2.699E-13	5.0959E-14	28.061	.000
Ethnicities	.199	.0113	310.643	.000
PositiveTemperature	-.012	.0025	22.333	.000
PositiveWater	-.002	.0008	10.372	.001

How negative water stress affects conflict was examined first. The negative binomial regression found a statistically significant relationship between conflict severity and increased temperature stress, as well as increased ethnicity density and the presence of a shared aquifer. All three of these variables were positively correlated with conflict intensity. The regression further revealed a positive correlation between negative water stress and conflict severity, and a negative correlation between GDP and conflict severity.

Looking at how positive water stress impacted conflict severity, strong differing regional trends were found. As a result, the regional variables were explaining nearly all the variance in the severity data. With all regions being included, the binomial regression did not find any statistically significant relationship between any of the intended independent variables and conflict severity. Looking back at the general statistics found for the positive water stress conflicts, Middle Africa had a much higher average fatality count, with a much larger standard deviation than the other regions. This region had significantly different conflict severity levels when dealing with positive water stress than the rest.

In order to test to see if the insignificant relationships in positive water stress conflicts were because the regional variables were masking a relationship between fatalities and the other right hand side variables, the dataset was split into two, one looking at the conflicts in Middle Africa, and the other looking at conflicts in Eastern, Northern, Western, and Southern Africa. Looking at the conflicts separately, statistically significant, though differing, results were found. Looking first at the Middle Africa region, GDP was not found to have statistically significant results. The presence of a transboundary aquifer had a negative relation to conflict severity, as did the number of ethnic groups. Positive temperature stress and positive water stress were both found to have statistically significant positive effects on conflict severity.

Moving onto the rest of Africa, the results were different. The presence of a transboundary aquifer was found to have a statistically significant positive relationship with conflict severity. The negative binomial regression found that GDP had a significant negative relationship with conflict severity, as did positive temperature and water stress. It also found that ethnicity density had a positive relationship with conflict severity.

In summary, H_0, that as positive water stress increases, so will conflict severity, had conflicting support from the data once the regional differences in positive water stress events were accounted for. There was a statistically significant positive relationship found in Middle Africa, with a statistically significant negative relationship found in the rest of Africa. H_1, that as negative water stress increases, so will conflict severity, was supported by the data with the negative binomial regression results. H_2, that as GDP of the country increases, conflict severity will decrease, had conflicting results. When looking at negative water stress conflicts, there was a negative correlation found with the negative binomial regression, which supports the hypothesis. In the positive water stress regressions, the relation between GDP and conflict severity was insignificant in Middle Africa, but was significant and negative in Southern, Eastern, Northern, and Western Africa. This could possibly be because other pre-existing issues supercede the effect of GDP in Middle Africa, or it could be because there is not as large of a disparity in GDP variance in Middle Africa as in the rest of Africa.

H_3, that increasing numbers of ethnicities in the area will result in increasing conflict severity, also had conflicting support from the data. Again, when looking at negative water stress, a significant positive relation was found. When looking at positive water stress regionally divided, however, only the negative binomial regression for Southern, Eastern, Northern, and Western Africa showed a statistically significant positive relationship while the Middle Africa region showed a statistically significant negative relationship. Again, this could be because other regional issues in Middle Africa supercede ethnic divides. H_4, that the presence of a shared groundwater source will lead to increased conflict severity, also had conflicting support from the data. A positive correlation was found during both negative water stress and positive water stress in Southern, Eastern, Northern, and Western Africa, though a statistically significant negative relationship was found in Middle Africa for the presence of an aquifer. Finally, H_5, that as positive temperature deviations increase, so will conflict severity, had conflicting support. There was a statistically significant positive relationship in negative water stress conflicts and in positive water stress conflicts in Middle Africa, but a statistically significant negative relationship in Southern, Eastern, Northern, and Western Africa. Essentially, all the hypotheses were supported when dealing with negative water stress conflicts, and in positive water stress conflicts the hypotheses had conflicting support.

These results mostly fit with previous studies. The relationship between temperature stress and conflict stress had been found in a few studies (Buhaug 2010; Irby 2017; O'Laughlin et al. 2012). The relation between ethnic divides and conflict severity has also been established in a number of studies (Casselli and Coleman II 2006; Irby 2017). In fact, one of the studies that found little evidence of a connection between drought and conflict found a connection between ethnic divides and conflict (Irby 2017). Theisen, Holtermann, and Buhaug (2012) found that while drought conditions do not make conflict more likely to occur, political marginalization along ethnic lines does. The connection between water stress and conflict has less established support. A number of studies found results supporting at least one of the kinds of water stress contributing to conflict frequency or severity (Burke et al. 2009; Hendrix and Salehyan 2012; Hsiang 2013), though some studies found that there was no relationship. Hendrix and Salehyan (2012), unlike this study, actually found definitive results that positive water stress is related to conflict. These studies tended to differ from this one because of differing definitions of what entails a conflict, inadequate environmental data, or because they were looking at conflict frequency, rather than conflict severity.

Many studies that do not support this finding have differing interpretations of what defines a conflict (Burke et al. 2009; O'Laughlin et al. 2012; Wischnath and Buhaug 2014). Theisen, Holtermann, and Buhaug (2012), for example, focused exclusively on large-scale conflict, requiring a certain minimum fatality rate in order to be classified as a conflict, thereby leaving out small-scale conflicts. Many of the conflicts over water resources, or even related to water stress, are not going to be interstate wars, and may not have fatalities (Homer-Dixon 1994). Many of the studies also (Brozek 2013; Gleick 1993; Wolf 1998; Yoffe et al. 2004) looked only at conflicts specifically classified as water conflicts, despite the fact that for water stress to contribute to a conflict does not require for it to be the only, or even just the primary, factor, or even for it to be identified by observers or participants as playing a role. It simply means that water stress affected the outcomes, regardless of who was aware of it. Other studies only looked a different and narrower region; O'Laughlin et al. (2012), for example, looked exclusively at Eastern Africa conflicts.

Some studies also had relatively coarse environmental data, using annual precipitation and temperature data, sometimes at the country-level, to apply to each conflict (Burke et al. 2009; Hendrix and Salehyan 2012). A few studies would only examine precipitation patterns to determine whether or not there was water stress, ignoring the existence of alternative water sources, such as aquifers (Burke et al. 2009; Irby 2017; Raleigh and Urdal 2007), while another study only looked at aquifer and surface water sources, and did not examine precipitation patterns (Wolf 1998). A number of the studies looked at the probability of conflict occurring, rather than severity (Burke et al. 2009; Hendrix and Salehyan 2007; O'Laughlin et al. 2012; Raleigh and Urdal 2007; Wolf 1998). Other studies measured conflict frequency rather than fatalities to measure severity (Hendrix and Salehyan 2012; Irby 2017). The strictly qualitative studies (Gleick 1993; Homer-Dixon 1994) lacked the systematic examination of large numbers of cases.

Discussion

There is much research left to be explored in this field. While this study looked at regional trends, there are significant environmental differences between different climate zones. This study attempted to counteract this bias through the use of standard deviations to evaluate precipitation and temperature changes, but different climate zones, such as arid regions to tropical regions, will have other environmental differences as well. Further research on this topic should look into how climate zones affect the impact of altered precipitation patterns on climate severity as well as whether or not the type of aquifer has any effect. Knowing how easily accessible the aquifer is, as well as whether or not it is rain-fed, would impact its usefulness in water stressed periods. Furthermore, expanding this research beyond Africa should be explored, as well as seeing what effect, if any, the type and strength of government has any conflict severity in a country. Politically speaking, tribal governments are less able to develop a comprehensive, enforceable policy than central governments, for example (Battig and Bernauer 2009; Sikainga 2009).

This study used Gross Domestic Product as an estimate of economic well-being, but further studies should also explore how agricultural outputs affect the vulnerability to water stress, especially in areas which are dependent on rainfed agriculture, as well as determining the economic status on a regional level in addition to the country level. More than half of the African continent's entire population depends on agriculture as a form of livelihood (United Nations 2013). Whether a country exports primarily natural resources will impact their vulnerability to climate change, and thus, their likelihood of experiencing climate conflicts. Countries whose trade depends on primary resources are in general also more prone to conflict, perhaps due to their inherent vulnerability to supply shortages (Humphreys 2003). The irrigation patterns could also explain the difference between regions. Most countries depend directly on rainfall; as temperatures increase and water distribution changes, agricultural water needs will change (Pauli 1996). Sub-Saharan Africa's agricultural sector is also 70% small farms, and in Africa as a whole 94% of cropland is rainfed (Gleick 1993; Taylor, Koussis, and Tindimugaya 2009, 660). Only nine African countries irrigate more than 10% of their cropland, and nearly 20 nations have effectively no irrigation supplies at all (Gleick 1993, 91).

Furthermore, more fine-grained regional analysis should be explored to determine why the positive water stress regressions had such differing results in Middle Africa as opposed to Eastern, Southern, Northern, and Western Africa, as well as analyses of the population patterns. Whether or not there is a significant difference in GDP distribution and ethnic group distribution between these two areas should be explored, as well as how the usage of groundwater differs and alternative water sources. Analyzing the data through the types of conflicts could also explain the differences in positive water stress conflicts, especially if there were conflicts with significantly greater fatalities in Middle Africa. The population patterns of the different areas could also have an influence. Rapid population growth, increased urbanization, especially in high-risk areas, and dependence on industries sensitive to climate such as rainfed agriculture are all risk factors to being vulnerable to water stress -- many African nations are experiencing all three (Brown, Hammill, Mcleman 2007, 1149; Taylor, Koussis, and Tindimugaya 2009; Theisen, Holtermann, and Buhaug 2012). Sub-Saharan Africa, for example, has one of the highest urbanization rates in world. By 2050, the region's urban populations are projected to triple that of 2000. These differences could account for the positive water stress conflict differences.

Conclusion

This study shows that increased water stress leads to more severe conflicts, especially in areas that are already going to experience more extreme consequences of climate change, and showed support for the hypothesized mechanisms, especially for negative water stress conflicts. First, when precipitation is abnormally low, there is more competition for water, and areas that have water sources that are shared are going to have more severe conflicts. Because there is that limitation on supply, it becomes more of an "all-or-nothing" dynamic. This is especially true in places with pre-existing divides, such as areas with many ethnic groups. Areas with low GDPs are also less able to cope with that decrease in precipitation, and are more likely to rely on rain for their survival, and areas that are predisposed to conflict are also more likely to experience severe conflicts. Africa in particular is vulnerable on all of these fronts. As a result of climate change, Africa will have higher temperatures and more extreme precipitation patterns (Brown, Hammill, and Mcleman 2007; Hendrix and Salehyan 2012; Taylor, Koussis, and Tindimugaya 2009). The continent already has large numbers of intrastate and interstate ethnic groups (Brozek 2013; Hitchcock 1993). Only about 5% of arable land in Africa is irrigated, leaving it dependent on reliable and steady rainfall (Taylor, Koussis, and Tindimugaya 2009). Furthermore, Africa has an extremely interdependent hydrological structure, and there are more water sources shared there than on any other continent (Brozek 2013).

These concerns and risks are not just limited to Africa. In the Middle East, strong ethnic divides characterize many countries in the region, with frequent rounds of infighting and influence from outside forces (Sarto 2017). Perhaps more so than in any other conflict, the Israel-Palestine relationship specifically demonstrates how water stress can be used as a weapon in conflict. Israel controls Palestinian access to water directly; the country blocks Palestinians from accessing the Jordan River through military power, forcing many Palestinians to buy water from the Israelis at inflated prices. Mekorot, the Israeli water company, supplies an estimated 50% of the water consumed in the Gaza Strip and West Bank. Residents in Israel and the settlements drink about three times as much water as Palestinians living in the West Bank do (Lazarou 2016). Throughout the year, water to the West Bank will occasionally be shut down, forcing the Palestinians to pay for water at a 500% markup from tap water (Asser 2010; Corradin 2016). This causes the Palestinians to leave or relocate due to a lack of basic supplies, such as sanitation and potable water. In turn, this makes it easier for Israelis to expand their settlements and develop more power in the area, and further justify an inordinate distribution of water (Corradin 2016).

Even in the United States, since 2000, a drought plagued the Southwest United States and Mexico, sending water levels plummeting in the Colorado River, among other bodies of water. Lake Mead, a reservoir in the Colorado river, reached its lowest point since the 1930s (Kennedy 2014). This reservoir and the river supply water for a 40,000 person population spread across seven states in the U.S. and two Mexican states. It also supplies agriculture in the United States that grows 15% of the nation's food (Snider 2016). While the United States may have the upper hand in control of the Colorado River, Mexico has control over the Rio Grande, which flows into Texas (Carter, Mulligan, and Seelke 2017). As a result, Mexico is able to have a card to play in negotiations where it otherwise would be at the mercy of the will of the United States and the international community's interference. In September of 2017, however, a new treaty was announced, called Minute 323, as an addendum to the 1944 treaty, which not only redistributed the river's water, but also actually allotted some to the environment for restoration.

In order to help prevent more severe conflicts as water stress grows, there are a few mitigation strategies that could be used, including water-sharing treaties such as that between Mexico and the United States. International governmental institutions have an effect on climate change and climate conflict (Wolf 1998). Mediation, arbitration, and alternative dispute-resolution mechanisms are all made possible, and more probable, with the presence of a trusted third-party organization. Having an international arbitrating body allows for the delegation of authority to that intergovernmental organization, thereby resolving the need for a power disparity. This allows the nations to have a third party monitor treaty enforcement, conduct conflict resolution, and ensure that joint monitoring is being conducted fairly and equitably. Agreements and treaties with these characteristics have been found to better manage water stress-induced conflicts, and there is evidence to show that mediation and cooperation can arise from water-stressed situations as well (Tir 2012).

Furthermore, international organizations may assist developing countries with creating development and adaptive capacities where individual countries are lacking. These organizations can also help developing countries skip over the carbon-intensive industrial practices once used by the developed world through technological and knowledge transfer (Salehyan 2008). In addition to international efforts, there also needs to be work done on the national and local scale. In the United States in particular, despite being a strong central democracy, voter opposition, misinformation, and a strong fossil fuel industry have severely curtailed the country's ability to develop long-lasting and effective climate change policy. Therefore, high voter participation is required to increase the chances of a democracy having effective climate change policy; voter participation can help lead to higher levels of public participation and government accountability, lower levels of corruption, and a farsighted government (Uddin 2017).

The increasing global temperature affects everyone, but not to the same degree and not everyone is equally vulnerable. Those that are the most vulnerable are also the ones most at the mercy of others. While these smaller, less-developed countries are the most vulnerable to both climate change and subsequently more severe climate change, the tragic irony is they are also the least able to personally impact the rising global temperatures (IPCC 2001). A country the size of the Philippines going completely green would still not save as much carbon emissions as a country like the United States decreasing their emissions by 95% (Global Carbon Atlas 2016). It is important to note that increased average per capita income in a country does not necessarily correlate to higher levels of environmental sustainability. In Robert Looney's 2016 study, he found "countries [that prioritized environmental sustainability]... had somewhat lower average per capita income ($25,015 vs. $37,095)." While more-developed countries freely used products that released greenhouse gases, less-developed countries are not able to without worsening their own situation. Areas that are particularly vulnerable to water stress include the Middle East and Southeast Asia, as well as many parts of Africa, meaning that other countries' interests in those areas are also vulnerable. Thus, a global effort must be undertaken to help limit the effects of climate change and also to help those that are most at risk prepare for what is to come.

Appendix

Table 9: Regional Assignments of African Countries by ACLED

Eastern Africa	**Western Africa**	**Middle Africa**	**Northern Africa**	**Southern Africa**
Burundi	Benin	Angola	Algeria	Botswana
Djibouti	Burkina Faso	Cameroon	Egypt	Lesotho
Eritrea	Gambia	Central African Republic	Libya	Namibia
Ethiopia	Ghana	Chad	Morocco	South Africa
Kenya	Guinea	Democratic Republic of Congo	Sudan	Swaziland
Madagascar	Guinea-Bissau	Equatorial Guinea	Tunisia	Zambia
Malawi	Ivory Coast	Gabon		Zimbabwe
Mozambique	Liberia	Republic of Congo		
Rwanda	Mali			
Somalia	Mauritania			
South Sudan	Niger			
Tanzania	Nigeria			
Uganda	Senegal			
	Sierra Leone			
	Togo			

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