Learning From Syria: Applying Environmental Modeling Toward Strategic Peacebuilding Interventions

Learning from Syria: Applying Environmental Modeling

Toward Strategic Peacebuilding Interventions

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Abstract

As climate change intensifies droughts and other extreme weather processes, much of the world will face freshwater scarcity, causing major challenges for food production. Without international support, these disruptions will likely lead to increased violent conflict and political destabilization. However, targeted interventions using environmental peacebuilding have the potential to prevent political breakdown, lessen migration, and ultimately help poor regions to achieve sustainable development. This thesis analyzes links between Syria's 2006-2010 drought crisis and subsequent instability and conflict at the subnational level as a case study to better identify precise locations in which drought and sociopolitical impacts are most intimately connected. To investigate this issue, a case study was conducted using GIS mapping of satellite data in combination with cluster analysis, multiple linear regression, and causal mediation analysis to identify locations within Syria in which the occurrence of drought significantly predicted subsequent migration and protest. These links proved the strongest in lush regions supporting intensive rainfed agricultural production and high population densities, suggesting that proactive, targeted environmental interventions to support agricultural productivity and water conservation in similar regions could prevent political violence and accompanying human suffering at significantly lower cost would post-conflict interventions. To lessen future conflict in the age of climate chaos, capable institutions should build on this research and, as soon as possible, act on it in identified key locations.

Dedication

   To future generations, and to my mentors. May we continue to fight together, with

a shared mission for the peace of humanity.

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Table of Contents

List of Tables

List of Figures

x

Chapter I

Introduction

Climate change impacts over the coming century are expected to weaken state security and spark resource-based conflicts, demanding creative new approaches to conflict resolution and prevention. To break the repeating cycle of increasing climate impacts, resource scarcity, and conflicts, conflict-prevention approaches must jointly tackle the problem of increasing greenhouse gas emissions while addressing threats to state security through strategic environmental protection and restoration efforts. Community-based efforts to enable environmental restoration and renewable energy development, combined with strategies that strengthen local governance, empower women, and heal ethnic divisions hold enormous potential to prevent resource-based conflict while fighting its root causes. Reducing greenhouse gas emissions, mitigating and adapting to climate impacts, and responding proactively to the crises they spark will require historically unprecedented injections of resources over the coming decades.

It is, however, possible to prevent many of these crises by breaking the cycle of climate change and conflict through timely, targeted interventions. This thesis aims to make such high-impact conflict prevention work possible by identifying types of geographic areas in which climate impacts and conflict are most strongly linked. To do so, it uses the crisis in Syria as a case study, using satellite data to identify the characteristics of subnational locations in which climate impacts led to migration and protest. In so doing, this study aims to lay the groundwork for future research enabling

identification of key locations for environmental peacebuilding intervention at a global scale.

Twenty First Century Climate Projections and Sociopolitical Impacts

According to recent best estimates by the Intergovernmental Panel on Climate Change (IPCC), the Earth's temperature will likely rise between 2.6 and 4.8 degrees Celsius by 2100 (Collins et al., 2013). This was the scientific consensus in 2013. According to a more recent study, Earth's atmosphere might be more sensitive to greenhouse gas emissions when it is warmer. If its findings are correct, Earth's temperature will likely warm between 4 and 7.4 degrees Celsius by 2100 (Shen at al., 2011).

The last time Earth's temperature reached six degrees Celsius above pre-industrial levels was roughly 250 million years ago, at the end of the Permian period (Burgess, Bowring, & Shen, 2014). At that time, a rapid increase in oceanic CO_2 levels led to a disruption of the carbon cycle and triggered a mass extinction event. During the End-Permian Extinction, over 90% of all species became extinct, and Earth's ecosystems took up to 10 million years to recover. Under these conditions, civilization would likely collapse.

If Earth's temperature rises by four degrees by 2100, sea level rise will force at least 1.3 billion people to leave their homes (Clark et al., 2016). Displacement of roughly half the projected world population, or about 5 billion people, would likely destabilize governments, increasing the likelihood of state failure. An exodus of refugees to more water secure nations may also create a domino effect, destabilizing nations otherwise capable of supporting their populations. The number of failed states is already increasing

due to water scarcity and other factors (Scudder, 2010). Even two degrees of warming, which Earth will likely reach by 2036 if fossil fuel burning continues at its current rate, will increase water scarcity, state failure, and conflict during the coming century (Mann, 2014). Countries in the Middle East and North Africa (MENA) region will be among those most impacted by water scarcity and increasing summer heat, compounding existing challenges in governance (Head, 2017).

The Environmental Conflict Paradigm: From Darfur to the Arab Spring

Conflicts over land and water resources, when fueled by worsening environmental degradation, can often last for years and prove resistant to conventional peace-making efforts. This has been the case in Sudan, which has been at war since 2003 when conflict broke out in the Darfur region. The conflict began when rebel groups rose up against the Arab-dominated government in Khartoum, accusing it of willful neglect of the Darfur region ("U.S. Stiffens Sanctions," 2007). The Darfur region lacked roads, schools, and water infrastructure, and had also been suffering from poor natural resource management exacerbated by climate change (United Nations Environment Programme [UNEP], 2007).

Over the past century, respected local councils have managed natural resources and successfully resolved resource disputes caused by seasonal fluctuations in water and grazing land (Hood, 2013; Amnesty International USA, 2009). However, the Khartoum government abolished the political authority of these councils in 1971 as part of an effort to consolidate power, which has limited their ability to protect resources and resolve conflicts successfully since then (Hood, 2013). Simultaneously, climate-induced drought, deforestation, and desertification in the Darfur region have stressed traditional

3

agricultural livelihoods and led to increasing conflict between groups competing for strained resources (UNEP, 2007).

The scale of environmental degradation in Sudan exacerbates the conflict by fueling ongoing tensions. In some locations, the degradation is so severe that peoples displaced by the conflict are unable to return to their homelands, thus depriving them of both homes and livelihoods (UNEP, 2007). A 2007 UNEP report found that lasting peace is unlikely in Sudan unless significant measures are taken to address the nation's widespread and accelerating environmental degradation. Overgrazing and deforestation, combined with declines in rainfall, have led to expanding desertification, leaving large swaths of land unable to support the nation's population, many of whom depend on agriculture and herding (UNEP 2007). Peace talks have centered on power sharing and monetary compensation, while the international community has largely focused its attention on war crimes perpetrated by military and rebel forces (International Coalition for the Responsibility to Protect, n.d.). These have been fairly common, conventional responses to international conflict resolution, which often do not recognize the critical importance of natural resources in conflict prevention and peacebuilding.

The conflict in Darfur is an illustrative forerunner of environmental conflict patterns likely to become increasingly common in coming years. A 2007 post-conflict environmental assessment by the UNEP predicted that climate impacts may cause the Darfur conflict to spread beyond Sudan's borders. In 2007, environmental impact models suggested that in parts of the Sahel, which spans across Africa from Sudan to Senegal, crop yields may decrease by up to 70%. These predictions have so far played out. Recurrent famine has plagued the region from 2010 until the present day (Johnson 2016).

The famine has triggered conflict in Mali, creating an increasingly complex humanitarian emergency (United Nations Office for the Coordination of Humanitarian Affairs [OCHA], 2017), while at least 15 million people across 8 countries remain in need of humanitarian assistance (ReliefWeb, 2017).

Additional studies have suggested high food prices caused by global climate impacts in 2010 also played a role in the Arab Spring revolutions. In Egypt, the world's largest wheat importer (IndexMundi, 2017), households spend an average of 38% of their income on food, and a third of those food calories come from bread (Croppenstedt, Saade, & Siam, 2006). When the price of wheat more than doubled in 2010 due to climate impacts--unusually intense droughts, heat waves, fires, and unseasonal rains-- across the globe (Werrel & Femia, 2013), Egypt's population, 28% of whom live in poverty, was stressed beyond its breaking point (Sternberg, 2013). Fueled by a growing inability to afford food, discontent over poverty and poor governance erupted in protests. Reminiscent of the 1977 Egyptian Bread Riots and 2008 food riots (Mahr, 2011), Egypt's January 2011 protests resulted in government overthrow, marking Egypt's inclusion in what soon became known as the Arab Spring ("Arab Uprising," 2013).

While climate change did not singlehandedly cause the Arab Spring, climate impacts, including food and water scarcity, urbanization, and migration contributed to political instability. Of these stressors, water scarcity was particularly severe. In 2009, Libya's renewable freshwater resources dropped to 95.8 cubic meters per capita, well below the UN scarcity level of 1,000 cubic meters (Sternberg, 2013; Food and Agriculture Organization of the United Nations [UNFAO], 2014). Additionally, desertification across the Sahel led to an influx of migrant workers, who by 2010 made

up 10% of Libya's population (Ratha, Mohapatra, & Silwal, 2010). In Yemen, dwindling water resources led to clashes over illicit wells in the lead up to the Yemeni Revolution (Friedman, 2012). Soaring food prices, an indirect result of the drought, also led to repeated violent protests in Algeria ("Fresh Rioting Breaks Out," 2011).

While analyses of the Arab Spring have correctly identified political grievances, ethnic and religious tensions, and poverty and inequality as primary causes, climate change aggravated all of these stressors, pushing countries ever closer to sociopolitical tipping points (Johnstone & Mazo, 2013). Climate change contributed to high food prices and shortages, which increased poverty. Drought, desertification, and consequently failed food crops forced many with agricultural livelihoods to migrate. While most of those displaced by drought moved only short distances, the disruption altered political dynamics, in some areas increased ethnic tensions, and provoked clashes over resources. As urban populations swelled with diverse newcomers, scarce jobs and inadequate infrastructure led to social conflicts and heightened disappointment over governments' inability to meet people's needs. Thus, the paradigm of environmental conflict played out from Sudan, to Mali, to Arab Spring nations. The pattern emerges just as vividly and deadly in Syria.

<center>Syria's Descent into Conflict</center>

The present violence in Syria is most directly a reaction to its brutal and distant regime, developing out of regional political upheavals since 2011 (Werrel & Femia, 2013). The focus of the conflict is regime change, but its triggers include religious and sociopolitical factors, an economic system that increasingly failed to meet the needs of its people, a wave of political reform sweeping the Middle East and North Africa (MENA)

region, and challenges associated with climate change and the availability of fresh water. In the years leading up to Syria's civil war, social, economic, environmental and climatic changes eroded the Assad regime's legitimacy, strengthening the case for the opposition movement. These include mass migration to cities and shortages of food and water stemming from a climate change induced multi-year drought that decimated food crops (National Oceanic and Atmospheric Association [NOAA], 2011).

From 2006-2011, up to 60% of Syria's land experienced, in the terms of one expert, "the worst long-term drought and most severe set of crop failures since agricultural civilizations began in the Fertile Crescent many millennia ago" (Nabhan, 2010, para. 4). According to a special case study from the 2011 Global Assessment Report on Disaster Risk Reduction (GAR), of the most vulnerable Syrians dependent on agriculture, particularly in the northeast governorate of Al Hasakah, "nearly 75 percent…suffered total crop failure" (Erian, Katlan, & Babah, 2011, p. 26). Herders in the northeast lost around 85% of their livestock, affecting 1.3 million people (Worth, 2010).

The human and economic costs were enormous. By 2008, rural farmers in Al Hasakah without remaining seed had begun migrating to already crowded cities, leaving behind malnourished children. By 2009, the United Nations (UN) and IFRC reported that over 800,000 Syrians had lost their entire livelihood as a result of the droughts (Syria: Drought," 2009). By 2011, the aforementioned GAR report estimated that the number of Syrians who were left extremely "food insecure" by the drought had reached approximately one million (Erian et al., 2011, p. 26). The number of people driven into

extreme poverty was even worse, with a 2010 UN report estimating two to three million people affected.

This led to a massive exodus of farmers, herders and agriculturally-dependent rural families from the countryside to the cities (Erian et al., 2011). In January 2010, it was reported that crop failures just in the farming villages around the city of Aleppo, had led "200,000 rural Syrians to leave for the cities" (Nabhan, 2010, para. 4). In October 2010, the New York Times highlighted a UN estimate that 50,000 families migrated from rural areas just that year, "on top of the hundreds of thousands of people who fled in earlier years" (Worth, 2010, para. 7). In context of Syrian cities coping with influxes of Iraqi refugees since the U.S. invasion in 2003, this placed additional strains and tensions on an already stressed and disenfranchised population (Wilkes & Dobbs, 2010).

This problem has been compounded by poor governance. The Assad regime, by most accounts, criminally mismanaged and neglected Syria's natural resources, which contributed to water shortages and land desertification (Werrel & Femia, 2013). Based on short-term assessments during years of relative plenty, the government heavily subsidized water-intensive wheat and cotton farming and encouraged inefficient irrigation techniques ("Syria: Drought," 2009). In the face of both climate and human-induced water shortages, farmers attempted to increase supply by increasingly tapping available groundwater resources, with Syria's National Agricultural Policy Center reporting an increase in wells tapping aquifers from "just over 135,000 in 1999 to more than 213,000 in 2007," which "caused groundwater levels to plummet in many parts of the country, and raised significant concerns about the water quality in remaining aquifer stocks" (Werrel & Femia, 2012, para. 8). Over-grazing of land and a rapidly growing population

compounded the land desertification process ("Act now to Stop Desertification," 2010).

As previously fertile lands turned to desert, farmers and herders had no choice but to

move in search of a new means of living, starve, or demand change.

Rural to urban population movements throughout the course of the drought

strained Syria's economically depressed cities, which already had deficient water

infrastructure ("Syria: Why the Water Shortages?" 2010). The poor and desperate were

forced to compete with each other not just for scarce employment opportunities, but for

access to water resources as well (Werrel & Femia 2013). According to Damascus-based

expert Francesca de Châtel, Syria experienced a "huge deterioration of [water]

availability per capita," partly as a result of a crumbling urban infrastructure ("Syria:

Why the Water Shortages?" 2010, para. 5). Disaffected rural communities also played a

prominent role in the Syrian opposition movement, even compared to their equivalents in

other Arab Spring countries (Watson, 2012). In a series of interviews by journalist

Thomas L. Friedman (2013), members of the Free Syrian Army shared that the

government's lack of response to the drought crisis pushed people toward revolution.

Indeed, the rural farming town of Daraa became the focal point for protests in the early

stages of Syria's revolution (Khan, 2011), a location among the worst hit by five years of

drought and water scarcity (Alami, 2011), with little assistance from the Assad regime

(Khan, 2011; Alami, 2011; Adorno, Alfieri, Di Peri, & Ferigo, 2011).

Failures in the Conflict Prevention Process

The conflict in Syria could have been averted at many stages had the precursor

conditions around drought been better appreciated alongside the nation's political issues.

It is possible that, had the Syrian government not responded to protests with violence,

regime change could have occurred without an outbreak into civil war and protracted conflict. At this stage, however, it would have been difficult for the international community to successfully intervene in a way that both prevented conflict and respected national sovereignty. Prior to the outbreak of protest, the international community had multiple opportunities to intervene in ways that would have improved relations between countries while stabilizing Syria's socio-political environment, creating a positive investment in Middle East peace as a whole. These intervention opportunities included timely injections of agricultural aid as well as earlier stage work centered on responsible water management.

The potential for conflict and instability in Syria was recognized as far back as 2008, when the United Nations released its first Syria Drought Appeal (OCHA, 2008). By that time, farmers without remaining seed had by begun migrating to already crowded cities, leaving behind malnourished children. A United Nations Inter-Agency study had determined that $20.23 million in aid were urgently needed to combat the drought's economic, social, and humanitarian fallout, which, according to the Syrian Minister of Agriculture, was "beyond [Syria's] capacity as a country to deal with" (Connelly, 2008, para. 5). Yehia predicted that, if Food and Agricultural Organization of the United Nations (UNFAO) efforts failed, mass migration from the northeast "could act as a multiplier on social and economic pressures already at play and undermine stability [in] Syria" (Connelly, 2008, para. 2). Farmers whose seed stocks and savings had been destroyed by the drought would have needed to purchase the next season's seeds on credit but hesitated out of fear that the drought would continue.

Thus, the UN Inter-Agency study conducted two months prior had determined that distribution of seeds in tandem with targeted food distribution were urgent and should have already begun (OCHA, 2008). The study also determined announcing assistance early would be important in convincing farmers to continue agricultural activities rather than migrate from the drought-affected areas. At that time, a pledge of aid would have allowed the UNFAO to borrow against the UN's Central Emergency Response Fund (CERF) distribute seeds to impoverished farmers before the winter planting season ended (Connelly, 2008). Had a pledge of aid been made, it is possible that Syria's civil war could have been prevented, significantly delayed, or limited in its area or scale.

The UNFAO's perspective conveys a systems-based approach to development integral to the UN's work (United Nations Economic and Social Commission [ECOSOC], 2004). This systems approach recognizes that problems of development are intimately linked and often share root causes. In Syria's case, the UN Country Team study had concluded that drought had led to food insecurity, internal migration, and in turn, social instability, predicting that "social destruction would accompany erosion of the agricultural industry in rural Syria" (Connelly, 2008, para. 5). The UNFAO's plan to avert social destruction through targeted aid to those most impacted thus adheres to a preventive approach common to the UN's international development work.

The international community, however, mobilizes aid primarily around crisis response rather than prevention. It also tends to evaluate aid responses more on meeting a shared social responsibility to contribute rather than on achievement of desired results. Recommendations from the US embassy in Damascus in the wake of the drought appeal

did not support pledging aid, and instead note that the US government had already contributed generously to events unfolding in Syria by providing aid to the large Iraqi refugee community there (Connelly, 2008). This stance, which aligns with American sentiments regarding foreign aid, seems to be that the U.S. was already doing its part given the constraints of limited funds, and should prioritize security over humanitarian issues. U.S. military and intelligence agencies were also notified due to the risk of emergent instability, but were encouraged to keep appraised of the situation rather than intervene (Frameworks Institute, 1999; Connelly, 2008). The recommendations thus contrast a more preventive approach that could have been taken.

Failures in the conflict prevention process indicate alternative approaches to maintaining security and U.S. interests in the Middle East were overlooked. This oversight, however, existed on a different level than might initially be expected. Key U.S. actors sought to undermine the Assad regime, which made maintaining stability in Syria appear counter to immediate U.S. interests. The first indication of such a strategy was in 2002, when Under Secretary of State John Bolton grouped Syria with previously named "rogue states," Iraq, Iran, and North Korea, saying that if it did not "renounce terror," the country could "expect to become one of our targets" ("US Expands 'Axis of Evil,'" 2002, para. 5). The statement would later be followed by a report out of Damascus, "Influencing the SARG [Syrian Arab Republic Government] in the end of 2006" that explored means of exerting influence in Syria. "We believe Bashar's weaknesses," the report states, "are in how he chooses to react to looming issues…. This cable summarizes our assessment of these vulnerabilities and suggests that there may be actions, statements,

and signals that the USG [U.S. Government] can send that will improve the likelihood of such opportunities arising" (Roebuck, 2006, para. 1).

As the protracted conflict in Syria demonstrates, however, an approach to exerting U.S. influence overseas that overlooks the importance of environmental stability is short-sighted. The Islamic State of Iraq and the Levant (ISIL) has achieved a stronghold in Syria; their controlled territory overlaps very closely with the drought stricken regions out of which Yehia predicted farmers would migrate (Gilsinan, 2014). The resulting conflict has created 6 million refugees outside of Syria and 10 million displaced people within the country (Brand & Lynch, 2017). Far from advancing U.S. interests or increasing its regional influence, the Syrian conflict has contributed to the spread of transnational terrorist organizations, destabilized the region as a whole, and made a return to stable governance seem a hope on the distant horizon.

Long-term environmental degradation and the destruction of environmental resources, such as water reserves and fertile soil, that are essential to survival creates long-term instability. Under pressure from enormous environmental challenges, any regime is likely to struggle to maintain rule of law. Sadly, under situations of conflict and resource scarcity, the only interests served are not those of local or international governments, but of those of groups who a) profit from sales of arms; b) control local trade routes, and can thus tax exchanges of goods at the local level; and c) are able to maintain control of scarce food and water resources, selling them at inflated prices to desperate local populations. Often, those groups benefiting are local armed militias, rebel groups, gangs, or terrorist organizations, in Syria's case, ISIS (Charles, 2014).

Even though U.S. attempts at influencing foreign governments have often yielded unsettling results, allowing environmental degradation to worsen in an already water-scarce and unstable region is particularly short-sighted (Grim & Delaney, 2016). Concerned leaders and institutions around the world have identified climate change and environmental destruction as one of the greatest current risks to stable global governance and growth (World Economic Forum [WEF], 2017). In the face of dire environmental threats, supplying traditional military assistance to foreign leaders to guarantee their support of U.S. interests is not a viable long-term strategy. In its place, U.S. agencies must learn the art of supplying assistance aimed at defending against environmental threats. In doing so successfully, the U.S. will have learned to secure its long-term interests in our increasingly interconnected world by engaging in environmental peacebuilding.

Environmental Peacebuilding for Global Stability

Climate change impacts and disputes over natural resources fuel violent conflicts worldwide, making integrating environmental resources into peacebuilding work essential. According to a 2009 report by the UNEP at least eighteen conflicts over natural resources have been fought since 1990 (Halle, 2009). Additionally, natural resources have played a role in at least 40% of all intrastate conflicts over the past sixty years. These conflicts are at least twice as likely to relapse into violence over the first five years than conflicts not complicated by natural resource concerns (Halle, 2009). This may be in part because fewer than a quarter of peace negotiations aimed at resolving these conflicts addressed plans for natural resource management.

A new approach will need to be taken to resolving conflicts over the coming century, as climate change and land degradation combine to weaken state security. In breaking the cycle between climate change, resource scarcity, and conflict, approaches centered on protecting natural resources by restoring the natural environment will be important at all stages of conflict from prevention, to containment and de-escalation, to long term peacebuilding. Community-based environmental restoration, combined with strategies that strengthen local governance, ensure community voice in broader political processes, and heal ethnic divisions, holds enormous potential to prevent and resolve conflicts and ensure lasting peace.

As a tool for peacebuilding, environmental restoration can often be a particularly helpful aspect of structural prevention, a group of activities including institution building, economic development, and grassroots community building (Johns Hopkins School of Advanced International Studies, 2015). Structural prevention is one of the most cost-effective methods of conflict prevention, a primary obligation of UN Member States (United Nations, General Assembly, Security Council [UNGA, UNSC], 2001). In order to be most effective, conflict prevention activities should be conducted as early and as comprehensively as possible, addressing developmental and institutional root causes of conflict rather than focusing simply on its immediate triggers. Such interventions are often highly cost effective. As of March 2016, Syria's conflict had already cost its own country $275 billion (Frontier Economics & World Vision International, 2016)). In addition, the US has spent $11.5 million per day fighting the Islamic State group in Syria since the beginning of Operation Inherent Resolve in August 2014 (Tomkiw, 2016). Given that the UN predicted $20 million in agricultural aid could have prevented the

conflict, conflict prevention efforts may have produced a return on investment worth over 10,000 times the initial cost. Earlier efforts aimed at improving water management and conserving soil quality, in combination with minor democratic reforms, would likely have paid for themselves in times of peace and been even more effective at preventing conflict in the long-term.

Protecting food and water resources from natural disasters such as drought and flood is central to conflict prevention. Restoring natural environments is one of the most effective and economical methods for doing so. Restoring natural environments helps protect agricultural land from drought by stabilizing rainfall patterns: Forests and other high vegetation ecosystems continuously release moisture through transpiration, seeding cloud formation in the surrounding area (Fraser, 2014). Forests and other diverse ecosystems help protect surrounding agricultural land from flooding by soaking up excess moisture and increasing the storage capacity of the soil (European Environment Agency, 2015). Additionally, these ecosystems strengthen the land's capacity to support agriculture and high population densities by increasing the capacity of nearby water basins. This helps protect cities and local agriculture from potential water shortage crises caused by groundwater depletion. At the international level, ecosystem rehabilitation also helps combat climate change itself by sequestering CO_2 back into the carbon-depleted soils (Schwartz, 2014).

In conflict and post-conflict situations, environmental restoration and management is not only a hurdle to overcome on the path to peace, but a means through which peace can be achieved. In peacebuilding, it is critical to manage conflicts' environmental causes and consequences, defuse tensions, and ensure that natural assets

are used sustainably, in a way that supports long-term stability and development (Nitzschke & Studdard, 2005). Additionally, shared management of natural resources can serve as a tool for peacebuilding in divided communities and between states. Carefully managed natural resources can encourage economic recovery after conflicts, contribute to the development of sustainable livelihoods, and build dialogue and cooperation between post-conflict groups (Halle, 2009).

Rwanda provides an excellent example of post-conflict recovery and future prevention through environmental rehabilitation and management. In the aftermath of genocide in 1994, the Rwandan government began to reform and rehabilitate the National Parks Management Authority and develop a lucrative tourism industry around endangered mountain gorillas (International Gorilla Conservation Programme, 2008). Tourists pay roughly $500 for a permit to observe gorillas, with similar amounts spent daily on luxury accommodation, meals, and transportation. The proceeds of environmental tourism serve both management of national parks and sustainable community development. In order to preserve gorilla habitat and other threatened environmental resources, the Rwandan government also signed the *Declaration of Goma* with the Democratic Republic of the Congo and Uganda in 2005 (Halle, 2009). This major accomplishment in international resource management served to demonstrate how environmental cooperation can help enable international dialogue, trust, and cooperation in post-conflict zones.

While Syria's conflict as of March 2017 has shown no signs of ending, post Arab Spring Libya can be used as a model of how peace talks can begin and plan for post-conflict environmental peacebuilding (Bowen, 2017). In April, Libya's two primary

warring sides reached a diplomatic breakthrough that has the potential to bridge lasting

compromise through a new political agreement (Wintour, 2017). While plans for

environmental restoration and water management may not have been discussed in full

detail yet, the Libyan National Oil corporation recently reached a $15 million sustainable

development agreement with Ebi North Africa to construct natural gas pipelines

powering hospitals, water desalination plants and other projects (Ben Ibrahim, 2017).

Detailed plans for sustainable environmental and water management will still need to be

implemented to strengthen opportunities for lasting peace, but the discussion of

infrastructure plans is a hopeful start (Femia & Werrell, 2012).

   While the current U.S. administration appears unlikely to engage in post-conflict

development in Libya, shared needs in providing for water security and environmental

management present an incredible opportunity for collaboration and the pursuit of shared

interests in the region (Wintour, 2017). The U.S. has long supported its allies Israel and

Jordan in research and technology development to provide for water and energy security

(United States Environmental Protection Agency, 2016; United States Department of

State, Bureau of Oceans and International and Scientific Affairs, 2000), an effort that has

brought the nations together and contributed to ongoing environmental peacebuilding

work between Israel and Jordan (Larson, 2016). In recent years, the U.S. military

presence in Iraq, Afghanistan, and other nations has shifted toward counterterrorism

partnerships and building trust through regional development (O'Connor, 2017;

Martinez, 2017; Fine, Linick, & Barr, 2016). As U.S. military forces and partnered

organizations work to build infrastructure and trust in the region, they would do well to

place a high priority on sustainable environmental and water management, efforts that have incredible potential to support the development of lasting peace in the region.

Military Roles in Environmental Peacebuilding: Precedent and Potential

The U.S. military has conducted environmental peacebuilding work across allied nations on multiple occasions, using these projects as opportunities to build trust with local communities. In 2015, as part of Operation Atlantic Resolve in Romania, members of the U.S. Army, Navy, and Marines helped a community plant trees in a nationwide effort to prevent deforestation (Wilson, 2015). The military also helps nations prepare for climate impacts by facilitating discussion between foreign militaries and their civilian counterparts and through partnership with communities. The U.S. Africa Command (AFRICOM), for example, engages in dialogue with government ministries, national militaries, and civil society groups about environmental issues to help build climate resiliency. AFRICOM has partnered with the UN Development Program (UNDP) on environmental rehabilitation projects in Togo and Senegal, and has hosted workshops on water and waste management in Ethiopia and Malawi (Cook, 2016).

While environmental peacebuilding is an activity that can, and should, be conducted in partnership with multiple organizations, there are distinct advantages to military involvement in the process. For militaries, environmental peacebuilding offers opportunities to stay sharp and ready in zones where peace is insecure while maintaining a positive presence and building good will with communities (Cook, 2016). The opportunity to participate in peacebuilding noncombatant roles also allows aspiring service members to feel good about their roles in protecting peace and stability without risking their lives in combat or suffering conflict-associated trauma. Communities also

benefit from the knowledge, experience, skills, and resources that military service members bring. Those communities most urgently in need of environmental restoration and sustainable energy and water infrastructure often struggle with a lack of government services, few material resources, limited rule of law, susceptibility to natural disasters, conflicts over natural resources, post-conflict tensions, or a combination of these challenges (Conca & Wallace, 2012). In these communities, military cooperation often plays an integral role in peacekeeping, conflict resolution, supply and transportation of critical resources, assistance constructing infrastructure, and on-call support in case of natural disasters (Last, 1995). They not only support civilian organizations by maintaining a peaceful environment, but are able to offer benefits through their highly trained career service members and often unparalleled resources (Cook, 2016).

In Afghanistan, for example, U.S. National Guard Agricultural Development Teams (ADTs) have successfully worked across agencies, building positive connections with local tribal leaders and improving agricultural productivity. ADTs have functioned as a platform for increasing dialogue and cooperation across peoples and tribes, working in collaboration with U.S. AID and the U.S. Department of State to conduct courses on agricultural productivity and support infrastructure projects while maintaining peace and order (Turner, 2010). Classes include basic gardening, bee-keeping, and livestock production, while larger infrastructure projects include watershed restoration and construction of water saving irrigation networks. A case study from Nangarhar Province suggests the ADTs have been highly effective there. The province is now one of the most stable in Afghanistan, allowing over 100,000 Afghans to return (The White House, Office of the Press Secretary, 2008). The province is now poppy-free and is now one of

the most agriculturally productive regions in the nation. Relations have also improved, benefitting counterinsurgency efforts there, and tribal leaders have requested additional ADTs to assist with long-term training and development (Turner, 2010).

While ADT work is one of the most effective peacebuilding interventions underway in the military today, these efforts receive only a tiny portion of military funding. The success of this work suggests that ADTs and other related noncombatant service branches should receive all the funding and support needed to expand and insightfully target their deployments, with the long-term goal of shifting U.S. military operations toward life-saving and highly cost-effective work in peacebuilding, conflict prevention, and post-conflict development. With climate change now a high-priority underlying threat to peace and security, expanding the military's environmental peacebuilding capacity and targeting it toward especially high-risk locations should occur as soon as possible. Effective targeting of environmental peacebuilding work will depend on the advancement of research that effectively combines current environmental data and near-term climate models with current research aimed at conflict prediction and prevention. This study aims to contribute to this crucial area of research by analyzing the relationship between drought, migration, and protest preceding the outbreak of violence in Syria. It is my hope that the insights gained from this study will help allow for improved conflict prediction models and ultimately aid in highly effective targeting of environmental peacebuilding work in the future.

Chapter II

Methods

To improve conflict predictions in drought-prone countries like Syria and develop

methods for better targeting environmental peacebuilding efforts, it is helpful to

determine in what ways Syria's drought contributed to its conflict. Did the drought, for

example, influence the likelihood that protest would occur in a given location, influence

the scale of ensuing violence, or both? Is the impact of drought on protest mediated in

any way by migration, as the UNFAO had proposed? Were there other environmental

determinants of migration or protest that may be relevant to environmental peacebuilding

efforts? A variety of analytical methods exist for examining these questions, including

cluster analysis, linear regression, and mediation analysis.

This study begins by using cluster analysis to create groupings of Syria's

subdistricts based on human, environmental, and land use factors, as well as explore

differences between those groups. Cluster analysis proved necessary because not all areas

of Syria experienced a connection between climate impacts and indicators of

sociopolitical instability such as protest. As expected, these links appear stronger in

densely populated locations dependent upon rainfed agriculture than they are in sparsely

populated desert locales. Exploring how the strength of these climate-conflict links

differs by location allows for improved awareness of their full extent and, critical to the

goal of this thesis, helps to identify types of locations where environmental peacebuilding

interventions can achieve the greatest impact. This analysis also allows subsequent regression models to explore the strength of trends in each cluster.

Next, linear regression analysis is used to explore how drought and other environmental factors may have impacted migration trends, as well as whether different subdistrict clusters display different relationships between environmental factors and migration. A probit regression then explores the relationship between migration and protest in the presence of different environmental factors. The linear and probit regression models are then combined in mediation analysis to distinguish between the direct effect of drought on protest and the indirect effect of drought on protest as mediated by population migration. Once this relationship is determined, the study further explores the relationship between drought, migration, protest, and conflict-associated deaths. First, linear regression analysis relates the number of conflict-associated deaths, a proxy for the scale of violence following protests, to the scale of the recent drought, while controlling for protest occurrence and population size. A second mediation analysis then combines this linear regression with the previous probit regression to explore the impact of drought on conflict-associated deaths, as mediated by protest occurrence.

To conduct the analyses for this study, I compiled a dataset combining information on geographic location, population across various years, cropland percentages, normalized difference vegetation index (NDVI) for multiple years, rainfall for multiple years, historical drought, protest occurrence, and number of conflict-associated deaths for each Syrian subdistrict. This dataset is the first of its kind combining environmental, climate, and population data with indicators of sociopolitical

instability at a granular, subnational level. I then used this data to construct variables for

use in each stage of analysis, as described in Table 1.
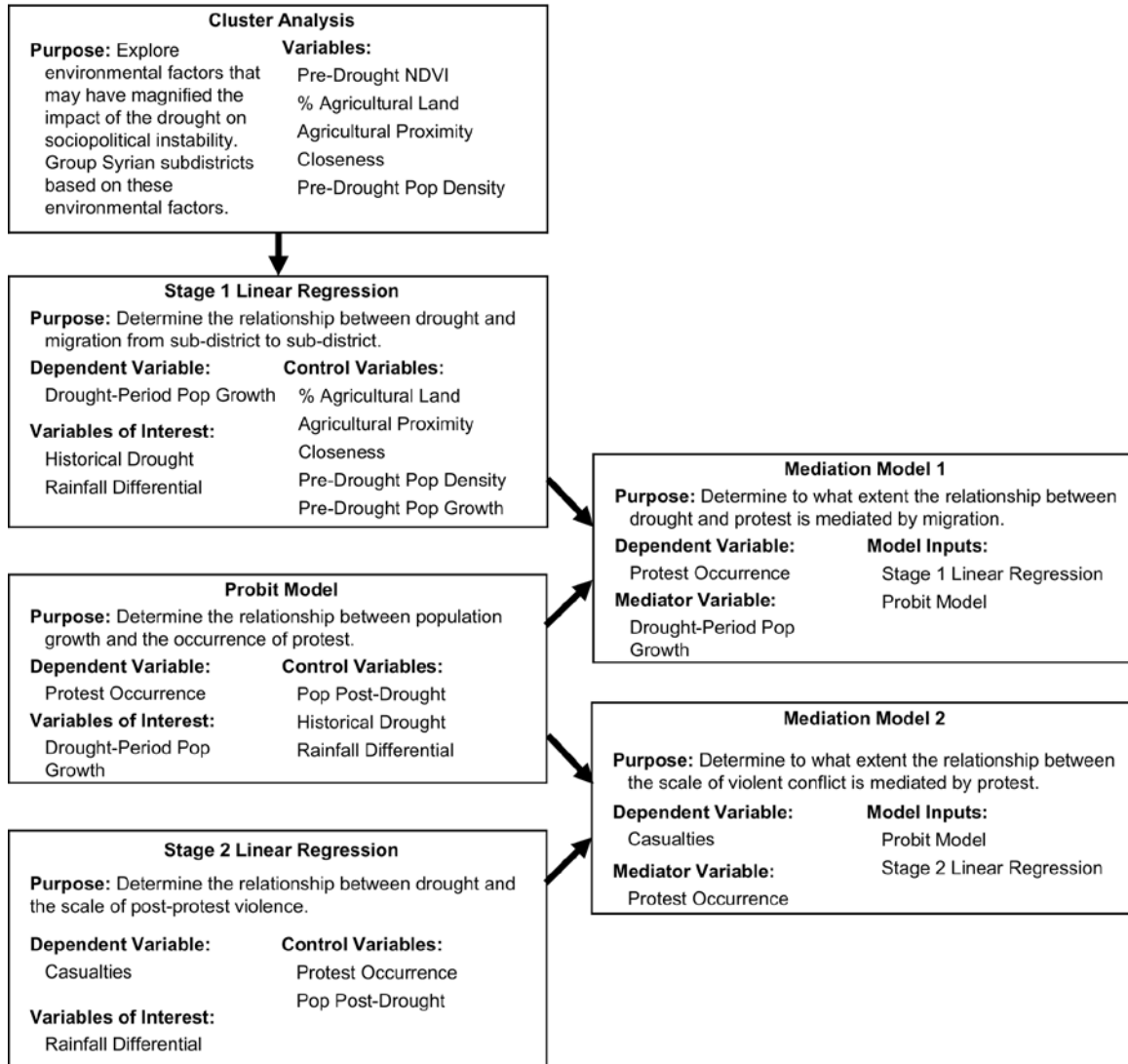
Figure 1. Analysis process, purpose, and variables used.

Dataset Assembly

This study relies primarily on satellite data, much of which is available in the

form of images or other geographic information systems (GIS) software compatible

formats, such as polygons or raster data. The first step in developing a location organized

dataset was choosing a location-based unit of analysis. Syria contains several

administrative divisions that are useful for comparing social and geographic trends. At

the highest level, Syria has 14 governorates, or *muhafazat*, which are divided into a total

of 65 districts, or *manatiq* (World Population Review, 2015). These are further divided

into subdistricts, or *nawahi*. Each subdistrict usually contains a city bearing the same

name, or a number of smaller towns or villages.

      Since Syria's subdistricts have clear geopolitical boundaries, and digital maps are

available at this level for data overlay and computation using GIS software, I chose to

compare geographic information at the subdistrict level. Choosing the subdistrict as the

unit of analysis resulted in an initial dataset with 272 data points. Subdistrict-level maps

of Syria are generously available from the UN Cartographic Section (UNCS) and UN

Office for the Coordination of Humanitarian Affairs (UNCHA) (2014) through Harvard

University's Geospatial Library. The mean area of each subdistrict is 691 km^2. Note that

Syria's more rural subdistricts are geographically larger, as they contain fewer people,

while the country's urban subdistricts tend to be smaller. Figure 1 map illustrates Syria's

subdistricts.
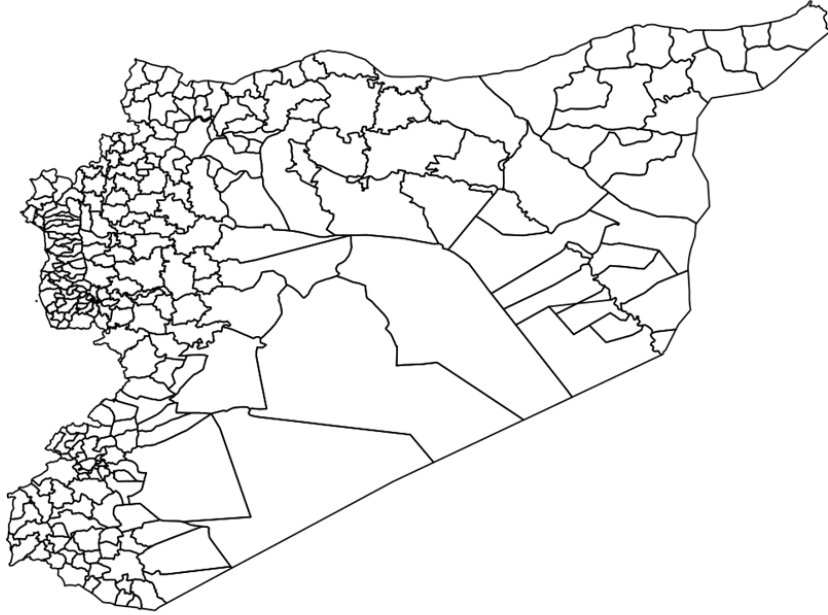
Figure 2. 2016 map of the 272 governmental administrative subdistrict boundaries of Syria.

This digital subdistrict map served as a base layer for all other datasets. In order to extract data for each subdistrict, other data sources were converted into raster data and then overlaid onto the Syrian subdistrict map. Using ArcMap, I then calculated the average raster value for each subdistrict. The dataset uses these averages in the construction of all other variables. Additionally, some variables rely on location-based data for measures of proximity to other subdistricts and agricultural centers. To make these calculations possible, I first generated the centroid of each subdistrict and determined its latitude and longitude in ArcMap. Distances between centroids were calculated in R as described in the Variable Construction section. Proximity-based variables take this distance between centroids as their input.

A number of variables in the study rely on population estimates to identify population density and growth rates at measured at times. These population estimates

were compiled from two data sources, (1) LandScan and (2) Gridded Population of the World (GPW). The LandScan dataset was created by Oakridge National Labs and GPW was created by the Center for International Earth Science Information Network (CIESIN). Both were made available through the Harvard University Geospatial Library (Oakridge National Laboratory, 2016).

The LandScan dataset uses a variety of data sources, including imagery of the sky at night, to develop estimates of the number of people living in a given area, to a 1 km^2 resolution. These data were overlaid onto the subdistrict map to generate the total population and population density for Syrian subdistricts in 2006, 2008, and 2010. The 2006 population density by subdistrict is shown as Figure 2.
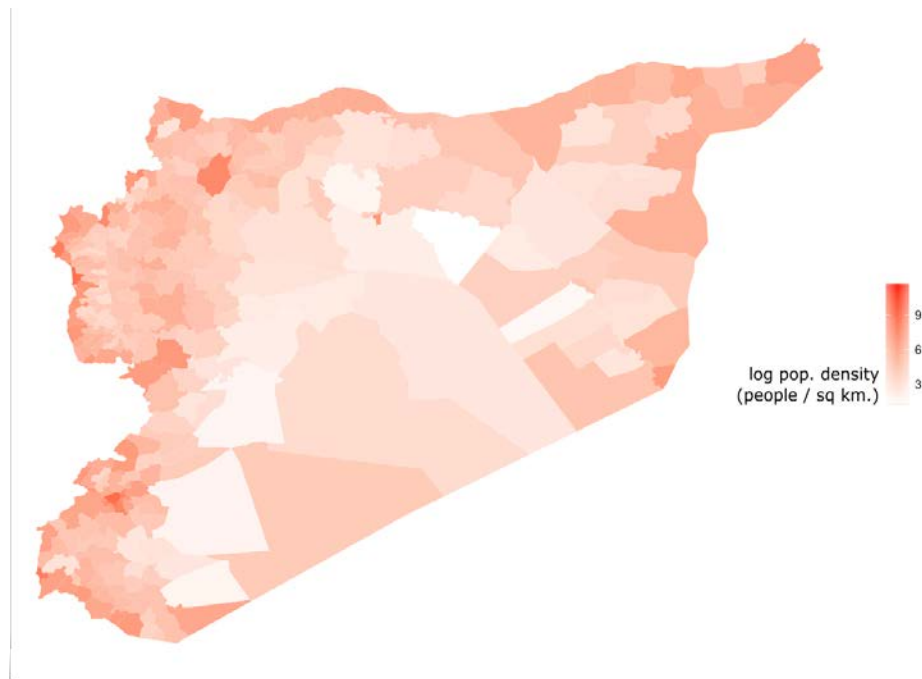
Figure 3. Map of population density of Syria, ca. 2006.

LandScan data overlaid on subdistrict map to determine population by subdistrict. Measured in persons per sq. km.

For the years 1990 through 2000, before LandScan estimates became available, population counts were similarly extracted from GPW (Center for International Earth Science Information Network [CIESIN], 2016). This dataset combines the most recently available census data from national statistics offices together with other available estimates and scales them as necessary by known population growth rates using the 2015 World Population Prospects estimates (Doxsey-Whitfield, et al., 2015). The GPW dataset, while used to determine population growth between 1990 and 2000, was not able to adequately measure migration during Syria's drought crisis because data was not available during all of the required years. Thus, LandScan data was used to determine drought period population counts instead.

Syria's NDVI data, used to explore differences in vegetation land cover, was assembled from the NASA Earth Observations Terra/MODIS NDVI Dataset (2014). Monthly NDVI data is available at 0.1 degree (11.1 km^2) resolution. The data consist of images obtained from NASA satellites. These images display where and how much green vegetation was growing at the time the satellite photographs were taken. See Figure 3 for a map of Syria's average annual pre-drought NDVI over the years 2000 through 2005 in each subdistrict.
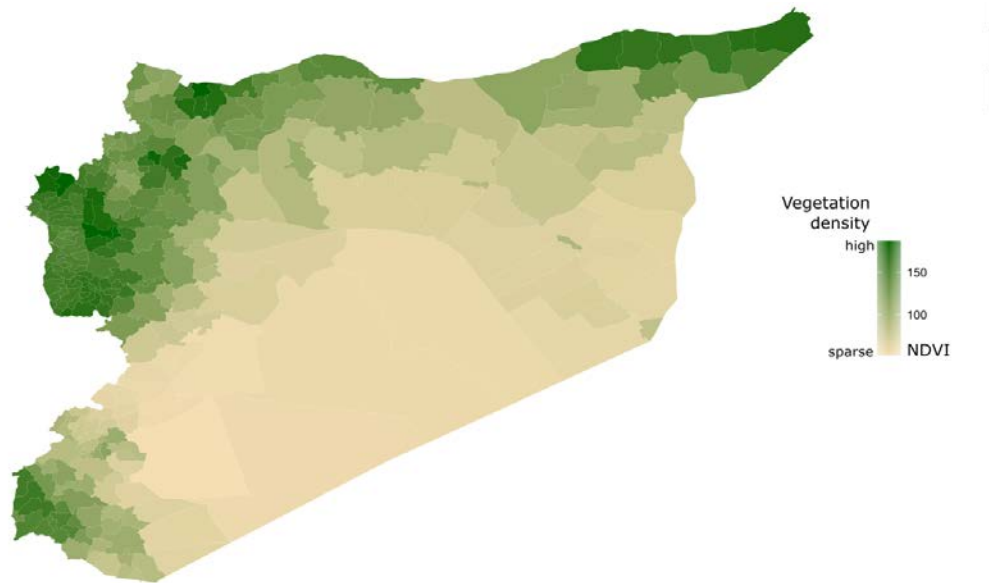
Figure 4. Map of Pre-drought (2000-2005) average Normalized Difference Vegetation Index (NDVI) throughout Syria.

Subdistricts are shown in colors that reflect the 6-year mean vegetation ground coverage as reported by NASA satellite monthly image data, 0. degree (11.1 km²) resolution.

Information on the percentage of cropland by subdistrict was obtained through the International Institute for Applied Systems Analysis (IIASA) Geo-Wiki Project (2005). Through the project, the IIASA in collaboration with the International Food Policy Research Institute (IFPRI) released a 2005 global cropland map in showing cropland percentages at 1 km² resolution. The map was developed by hybridizing data sources contributed by multiple organizations and validated by a crowdsourced network of volunteers (IIASA, 2005). Data on cropland percentages were obtained directly from the project and overlaid onto the subdistrict-level map as described previously. Figure 4 illustrates the percentage of cropland by subdistrict.
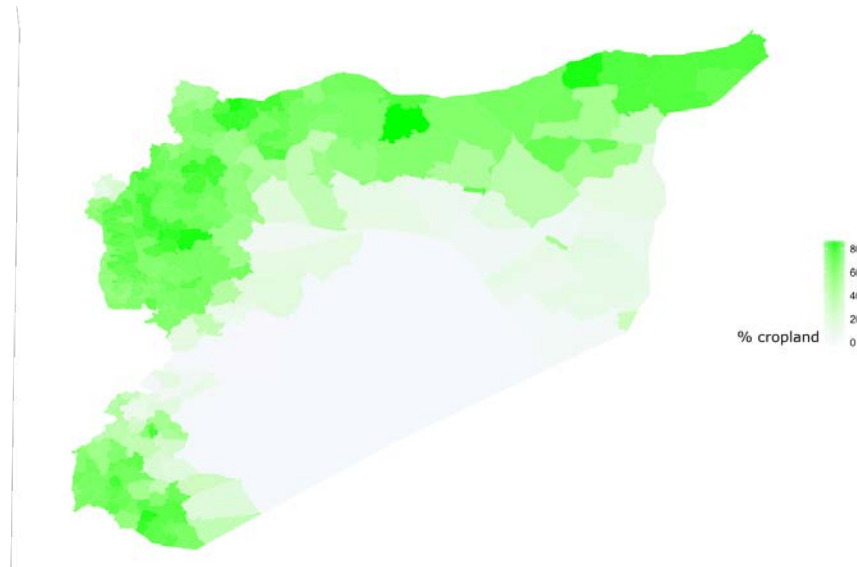
Figure 5. Map of percentages of Syrian subdistricts devoted to agriculture, 2005.

Data from the International Institute for Applied Systems Analysis (IIASA) Geo-Wiki Project is overlaid on the administrative map of Syria to show percentage of active cropland in each subdistrict.

This study also incorporates data on the intensity and duration of Syrian droughts over the past century. Drought data comes from the World Resources Institute (WRI) Aqueduct Global Maps 2.1 dataset (2014, 2015). The WRI dataset estimates the average length times the dryness of droughts from 1901 to 2008, where drought is defined as a continuous period during which soil moisture remains below the 20th percentile, dryness is defined as the number of percentage points below 20th percentile, and length of time is measured in months (Sheffield & Wood, 2007). The WRI dataset takes soil moisture data available at 1 degree (111 km^2) resolution and averages these across hydrological catchments. To determine the average historical drought intensity for each subdistrict, I took this output and overlaid it onto the subdistrict map, as described previously. Figure 5 illustrates the estimated historical drought severity for each subdistrict.
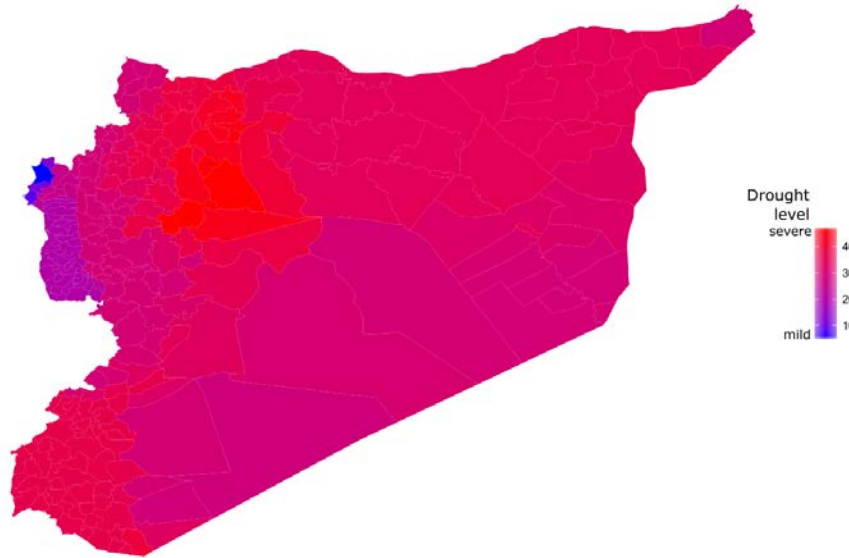
Figure 6. Per-subdistrict map of average historical (1901-2008) drought severity in Syria.

World Resources Institute data is overlaid on the Syrian political subdistrict map to identify long term drought severity for each subdistrict. These data are estimates of drought periods during which soil moisture is < 20% of expected normal, multiplied by length of time in months.

To determine the impacts of the more recent drought, this study uses rainfall data from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), which reports rainfall estimates in millimeters (University of Santa Barbara, Climate Hazards Group, 2015). To create high resolution (0.05 degrees/5.55 km^2) rainfall data, CHIRPS combines satellite imagery with local weather station data to create a gridded rainfall time series. This study combines the mean annual rainfall data available from CHIRPS to create a multi-year average for the years 1981 through 1999, and in 2006 to create a comparison between rainfall before the drought and during the drought. Comparing the drought and pre-drought rainfall yields the following rainfall differential, measuring the amount of precipitation in millimeters in 2006 above the pre-drought

average. Figure 6 shows large portions of Syria's agricultural land experienced severely

reduced rainfall in 2006, as indicated in brown.
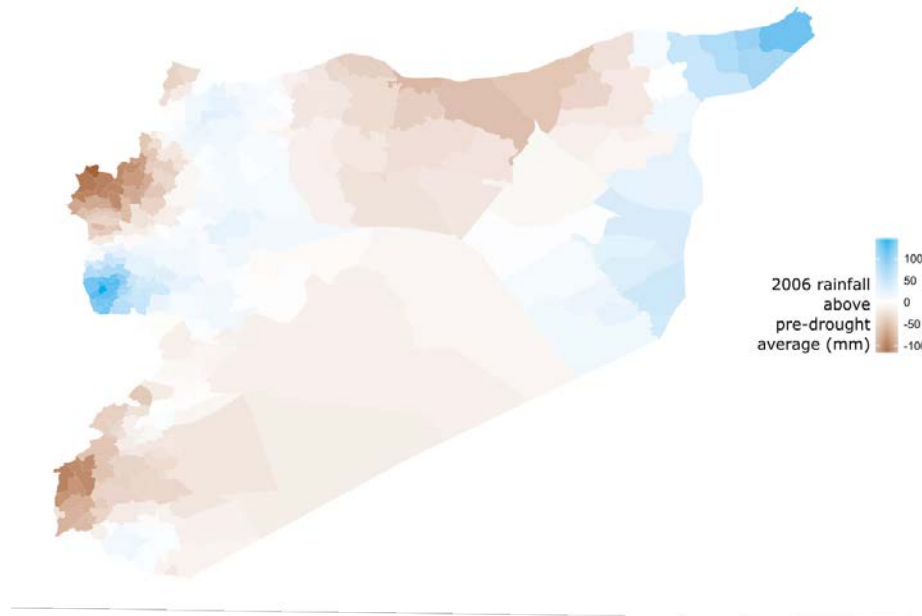
Figure 7. Syria. 2006 annual rainfall differential measured in millimeters of precipitation
above pre-drought (1981-1999) average.

*Comparing average precipitation from 1981 to 1999, as reported by the Climate Hazards
Group CHIRPS dataset, to 2006 precipitation levels shows the impact of immediate
drought on each Syrian subdistrict.*

For the primary outcome variable, whether or not protest occurred in a given

subdistrict, this study relies on reports aggregated by a number of different sources. The

first of these is a data compilation by the Local Coordination Committees of Syria

(LCCSY, 2017), which includes mapped protest data by city from the beginning of the

Syrian uprising through June of 2011. Due to the ongoing conflict, the LCCSY has not

maintained a consistent web presence, thus making some of the original protest maps

unavailable. This study tracked the available data aggregated by the LCCSY and

preserved it in tabular format. LCSSY (2013) also accommodates email enquiries regarding protest data.

In addition to the maps compiled by the LCCSY, this study relied on a compilation by Khatib and Lust (2014), as well as additional news sources charting the escalation of protest during the initial months of the uprising, which are listed in Appendix II. While it may not be possible to determine with certainty the location of every protest in Syria, every effort was made to chart protests as comprehensively as possible. The red areas in Figure 7 indicate subdistricts in which at least one protest occurred.

Figure 8. Syria. Reported political protests, March - June 2011.

Syrian administrative subdistricts displayed in red had at least one report of a political protest between March and June 2011. These data were compiled from the Local Coordination Committees of Syria, Khatib & Lust's 2014, Taking to the streets: The transformation of Arab activism, and many contemporaneous news reports.

In addition to protest data, this study uses information on conflict-related casualties, that is, the number of civilian deaths that occurred as a direct result of the

conflict, as an indicator of the scale of violence in each subdistrict. Data on the number of casualties by subdistrict was obtained through the SyriaTracker, a project of Humanitarian Tracker (2016). SyriaTracker maps crowdsourced casualty information in cooperation with the Center for Documentation of Violations in Syria. While civilian deaths are underreported for a multitude of reasons, these data are the most reliable confirmed casualty information available at the subdistrict level. Information on the cause of death for each casualty recorded can also be found through SyriaTracker. In order to avoid potential confounding as a result of later ISIS incursions and other outside factors, this study uses casualty data from the first year of conflict through May 2012. While casualties have mounted as the conflict continues, they continued to remain clustered around the same locations as those depicted below. Figure 8 illustrates the number of confirmed civilian casualties in each subdistrict.
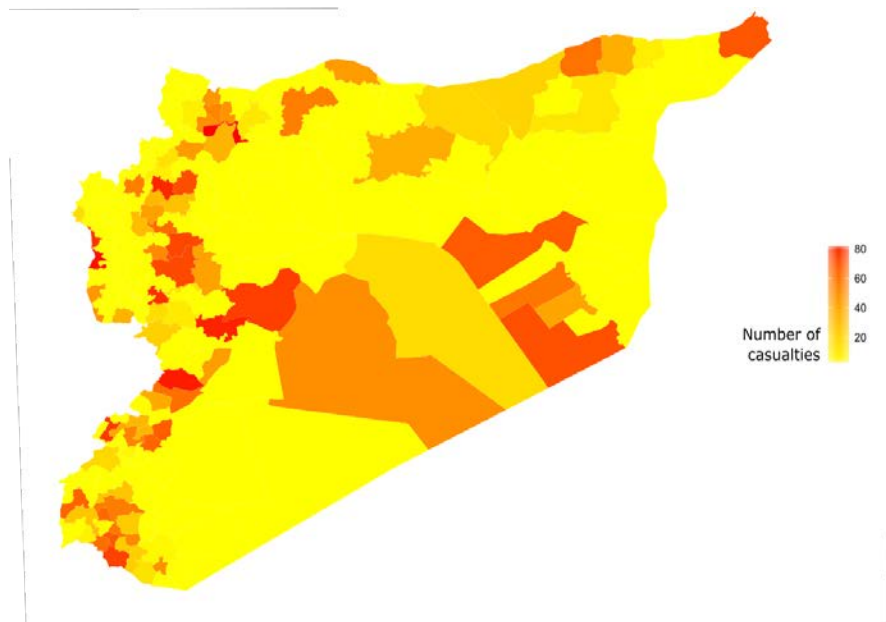
Figure 9. Number of confirmed civilian casualties by subdistrict, from outbreak of conflict to February 29, 2016. Data obtained through SyriaTracker.

Variable Construction

This study makes use of several variables constructed from the data sources above. These variables can be broadly categorized as population factors, environmental factors, distance factors, and sociopolitical outcomes, though each has a more precisely defined role in multiple forms of analysis. Variable roles in analysis are described in more detail in subsequent sections. This section details how each variable was constructed, what it indicates or serves as a proxy for, and the reasons for choosing its particular construction.

Population Factors

This study makes use of several population variables, including the compound annual growth rate (CAGR) of subdistricts' populations for the years 1990 to 2000, the logarithm of the population density of each subdistrict in 2006, the CAGR of subdistricts' populations from 2006 to 2008, and the logarithm of each subdistrict's total population in 2010. The CAGR from 1990 to 2000 was used to indicate a baseline population growth rate for each subdistrict. It serves as an important control variable because rural subdistricts tend to have higher population growth rates. When it is controlled for, the relationship between the population's CAGR during the drought period and various environmental variables can be more reasonably attributed to migration, rather than differences in birth rate between urban and rural areas. To determine the population's CAGR from 1990 to 2000, I subtracted the 1990 population from the 2000 population (provided by the GPW dataset), and then used the standard formula for computing CAGR. The R code is used to make this calculation is included in Appendix II.

The logged population density in 2006 was used to indicate how urban or rural a subdistrict was overall, as well as serve as another control that might have influenced population growth and migration during the drought crisis. This is control is important because a) birth rates tend to be lower in urban centers, and b) sources suggested that people tended to migrate from rural to urban centers during the drought (Lyon, 2010; Kilcullen & Rosenblatt, 2014). To determine the logged population density, first the total population in each subdistrict as reported by the LandScan dataset was scaled by the World Bank's population estimate for Syria in 2006, as detailed in Appendix II. The scaled population estimate was divided by the subdistrict's area, and the result was logged. The log of the population density is used in this study because it is linear in relation to other factors, whereas the population density itself displays nonlinear relationships with other variables.

As an indicator for migration during the drought crisis, this study uses the CAGR of subdistricts' populations from 2006 and 2008. These years were selected, even though the drought continued beyond 2008, because drought-induced migration appears to have been most significant during the first two years of the drought crisis. Much of the migration that occurred prior to the onset of unrest likely took place within these years. To determine the CAGR for each subdistrict, 2006 and 2008 population counts were obtained using the LandScan dataset and scaled according to World Bank estimates as before. Then the CAGR was calculated using the standard formula, as before. The R code detailed in Appendix II illustrates this process.

This study also uses the logarithm of the population of each subdistrict in 2010 as an aid in comparing protest occurrence and number of casualties. This control was used

because protest occurrence in early 2011 appears to be in part a function of population size. That is, protests were more likely to be organized and/or broadly reported on in locations with more people. Additionally, the number of conflict-induced casualties in each subdistrict also scales linearly with the subdistrict's logged population. The logged population in 2010 was calculated in the same manner as for 2006, by using the LandScan dataset and scaling it according to the available World Bank data, as detailed in Appendix II.

Environmental Factors

This study makes use of four environmental variables: each subdistrict's (a) NDVI prior to the drought, (b) percentage of agricultural land, (c) rainfall differential experienced in 2006 as compared to average rainfall before the drought, and (d) historical experience of drought. A subdistrict's average pre-drought NDVI refers to its average annual NDVI spanning the years 2000 through 2005. Although rainfall in Syria had been decreasing prior to this time, high resolution NDVI data for Syria first became available in 2000. Thus, these six years provide the best estimate of typical NDVI values prior to the beginning of the drought crisis. Specifically, the average pre-drought NDVI relies on the NDVI for April of each year, during the peak of Syria's winter wheat crop when farmlands are generally the lushest (United States Department of Agriculture, Foreign Agricultural Service, 2012; UNFAO, 2012). NDVI values during this month thus indicate areas of healthy agricultural production as well as year-round vegetation. To calculate the pre-drought NDVI, April NDVI values were averaged across the six selected years.

Data on the percentage of cropland in each subdistrict was extracted directly from the data's original source, as described previously, without need for further processing.

Cropland percentage serves as an indicator for the importance of farming within a given subdistrict, in particular, the number of farmers in the subdistrict who may have been impacted by drought, as well as the importance of agriculture to the local economy. These factors are drivers of rural disaffection linking drought to protest. Cropland percentage was chosen as the farming indicator variable because the high resolution at which cropland data is available makes analysis possible at the subdistrict level.

The rainfall differential in 2006, as compared to average rainfall before the drought, serves as a primary indicator for the severity of the drought crisis in each subdistrict. The year 2006 was selected for comparison because it falls at the beginning of the drought and migration period and likely had a greater overall impact on seed stock and migration than did rainfall in subsequent years. While drought-period annual rainfall differentials are fairly consistent across years, rainfall in 2006 likely had the greatest overall impact on migration between 2006 and 2008, the period under analysis. While Syria first began experiencing severe drought conditions in 2006, rainfall levels had been decreasing since the year 2000 (Erian et al., 2011). To account for this decrease, this study used the twenty-year period between 1981 and 1999, the first twenty years during which high resolution data was available, to calculate a pre-drought rainfall average. To calculate the rainfall differential, the average pre-drought rainfall was subtracted from the rainfall in 2006. Thus, positive values for this variable indicate increased rainfall during the drought period, while negative values indicate decreased rainfall during the drought period.

Historical drought serves as a measure of drought over the past century. This measure is an estimate of the average length of each drought, multiplied by the dryness of

38

each drought, from 1901 to 2008. Construction of this variable did not require any additional calculation, but rather was available directly from the Aqueduct Global Maps data source. This metric is helpful for two important reasons. First, historical drought impacts the water table in each location. Areas that are significantly more drought-prone are likely to have depleted groundwater resources, which reduces farmers' ability to supplement rainwater with well water for crop irrigation in years of low rainfall. Second, climate change tends to exacerbate conditions in already drought-prone areas, meaning that areas of historical drought are likely to experience the greatest rainfall shortage during the current drought period. Based on these avenues of impact, one would expect historical drought to significantly predict migration during the current drought crisis.

Distance Factors

This study takes into account two distance-related factors, *closeness* and *agricultural proximity*. Closeness serves as an indicator for how near a given subdistrict is to major population centers. To calculate closeness, I first determined the geographic center of each subdistrict in ArcMap, and then determined the proportion of Syria's total residing in each subdistrict according to LandScan's 2006 population data. This population proportion was then multiplied by the inverse of the distance separating each pair of subdistricts. Appendix II illustrates this process in detail.

Subdistricts that are closer to other subdistricts with high proportions of the national population thus have higher closeness scores. Controlling for closeness to other population centers is important because families choosing to migrate are likely to move to densely populated locations that are close by. The closer a subdistrict is to other

population centers, the more likely migration is to have played a role in its population dynamics.

Agricultural proximity is a measure which, similarly to closeness, indicates how near each subdistrict is to other agricultural lands across the country. It is a weighted sum of two variables. The first is the inverse of the distance separating each pair of subdistricts. The second is the percentage of agricultural land in each subdistrict. To calculate agricultural proximity for each subdistrict, the inverse distance between it and another subdistrict is multiplied by the percentage of agricultural land in the second subdistrict. These results are then summed across all subdistricts to get a metric of overall agricultural proximity for each one, as detailed in Appendix II. As a result, subdistricts that are, overall, nearer subdistricts that engage in more agricultural production have higher agricultural proximity scores. Controlling for proximity to agricultural lands is important because, when those lands are hit by drought, they are likely to become sources of migrants.

Sociopolitical Outcomes

This study also includes two outcome variables: a) the occurrence of protest and b) the number of casualties in each subdistrict. Protest occurrence serves as an indicator of sociopolitical instability in a given subdistrict, allowing this study to make connections between drought, migration, and instability more generally. Protest occurrence is a binary variable: either protests occurred in a given subdistrict or they did not. Thus, its value is the same regardless of how many protests ultimately occurred in a given location. Protest was treated as a binary variable because the data was not suitable for treatment as a

continuous or factor variable, and because one protest often itself increases the likelihood of subsequent ones in the same location.

The number of casualties in a given subdistrict serves as an indicator for the scale of violence in that location following the protest phase of the uprising. This study includes the scale of violence by location because, given protest and corresponding regime crackdown, the drought crisis may have increased the desperation of those who were protesting, thus escalating protests and causing ensuing nearby conflict to become deadlier. The number of casualties comes directly from data compiled from the Violations Documentation Center (2013, 2018) and did not require further calculation.

<div align="center">Cluster Analysis</div>

I had initially hypothesized that Syria's population dynamics would present a clear example of rural-to-urban migration, in which families from sparsely populated agricultural lands migrated to densely populated cities in search of new employment opportunities following repeated crop failure. A quick comparison of Syria's population centers with the country's agricultural land, however, suggested that this framework for analysis would be inadequate in characterizing Syria's population dynamics. Agriculture has historically been the most important factor in Syria's economy and national well-being, to the extent that it has determined much of the country's settlement patterns and locations of high population density (Sarris, 2004). A side-by-side comparison of mapped data suggested that Syria's population centers and agricultural lands correspond significantly. That is, most of Syria's major cities are agricultural centers, surrounded by fairly densely populated agricultural lands.

In the absence of a clear rural-urban divide coincident with agricultural development, I used cluster analysis to determine whether other clear distinctions appear in Syria's population distribution. To check for the existence of clusters, I analyzed the following five variables, again using Syrian subdistricts as my unit of analysis:

- Pre-drought average NDVI

- Percentage of agricultural land

- Agricultural proximity

- Population density

- Closeness (geographic)

I then ran *k*-means cluster analysis using these five variables as inputs to determine whether Syrian subdistricts naturally aggregated into any clear clusters, and if so how many. Three clusters initially emerged, so this value was used as an input into the *k*-means analysis. The R code used for this analysis is shown in detail in Appendix III.

Regression Analysis

The causal mediation analysis employed in this study relies on two different regressions examining the links between a) drought and migration and b) migration and protest. The first is a linear regression of compound annual population growth from 2006 to 2008 against related controls and potential indicators of drought. The second is a probit regression of protest occurrence on drought period migration, potential drought indicators, and a population control. Together, these analyses explore to what extent

Syria's drought drove migration and, through this migration, protest, thus forming the backbone of subsequent causal mediation analyses.

Linear Regression: Population Growth

I began by testing the claim that the Syrian drought crisis resulted in mass migration as indicated by population growth, an outcome that Syrian UNFAO minister Yehia had warned would result in sociopolitical instability. To determine whether indicators of drought were determinants of population growth, I regressed the compound annual population growth from 2006 to 2008 against the following seven variables:

- Logged population density, 2006 (control variable);
- CAGR, 1990 to 2000 (control variable);
- Closeness (geographic control variable);
- Percent agricultural land (control variable);
- Agricultural proximity (geographic control variable);
- Historical drought;
- Rainfall differential; and included an interaction term between historical drought and agricultural proximity.

The R code used to conduct this analysis is detailed in Appendix II. Of the above seven variables, the first five serve as controls. The logged population density in 2006 is controlled for to account for inherent differences in population growth in urban and rural areas. Controlling for population density is important because less densely populated parts of Syria often have less access to services, including family planning, resulting in significantly higher birth rates. Since annual growth rates are likely to be relatively stable

over time the CAGR for the population of each subdistrict from 1990 to 2000 is also controlled for because doing so allows for more accurate determinations of the impact of drought on growth. Closeness is controlled for due to the impact that proximity has in determining migrants' destinations. Additionally, the percentage of agricultural land is controlled for because agricultural centers are likely to be impacted by migration, both inbound due to their role as economic centers and outbound in the case of drought. Agricultural proximity is also controlled for because migrants likely traveled to their destinations from nearby agricultural lands.

The remaining two variables, historical drought and the 2006 rainfall differential, are primary quantities of interest in relation to migration. Historical drought and the rainfall differential at the beginning of the drought crisis together likely influenced not only the health of primarily rainfed crops, but also the height of water tables which would determine whether farmers were able to irrigate their land. My hypothesis was that these two variables would significantly correlate with migration, as indicated by population growth rates, at the subdistrict level. Additionally, this regression accounts for the interaction between historical drought and agricultural proximity. I originally regressed the seven above variables without this interaction term. However, running a generalized additive model and plotting the results revealed nonlinearities in historical drought and agricultural proximity, suggesting the possibility of interaction terms. Interactions between the two variables are intuitive because drought-prone areas are less likely to be developed as agricultural centers over time.

Since much of Syria consists of sparsely populated desert land, I expected Syria's drought to have most significantly impacted migration in dense population centers that

were near much of Syria's lush agricultural lands. Because expected relationships varied, I applied this linear regression model not only to the country as a whole but to each group of subdistricts that emerged from the previous cluster analysis. I also further examined the interaction between historical drought and agricultural proximity, particularly how population growth and proximity are related under different drought regimes.

Probit Regression: Protest

After investigating the relationship between drought and migration, I conducted a probit regression of protest occurrence on the log of each subdistrict's 2010 population, the population's CAGR during the drought crisis, historical drought in the area, and the 2006 rainfall differential. The purpose of this analysis was to determine whether migration, as indicated by drought-period population growth, historical drought, and rainfall differential significantly predicted protest occurrence. As total population significantly predicted protest, or at least reports of protest, regardless of other factors, this analysis controlled for the 2010 population, the most recent measure of population available prior to the occurrence of protest. The probit regression tested this relationship on both Syria as a whole and separately by cluster, as detailed in Appendix II.

Causal Mediation Analysis

This study also employs causal mediation analysis through the R package 'mediation' to explore the pathways through which Syria's drought conditions influenced later protest occurrence and political violence in each subdistrict (Tingley, Yamamoto, Hirose, Keele, & Imai, 2017). Causal mediation allows for the identification of mediating variables through which treatments causally affect outcomes (Imai, Keele, & Tingley,

45

2010). In its identification of mediated versus direct causal pathways, mediation

outperforms two-stage least squares regression by allowing for exploration and

comparison of both direct and indirect pathways during analysis. Because direct and

indirect pathways may have opposing influences on outcome variables, causal mediation

is thus able to uncover effects that may otherwise remain hidden. This feature proved

invaluable to this study, enabling the identification of dual causal pathways through

which drought impacts sociopolitical instability, effects that would have been obscured in

alternate forms of analysis.

In order to make causal inferences, mediation analysis relies on the sequential

ignorability assumption. This assumption includes two components: Conditional on the

observed pretreatment and treatment covariates, a) the treatment variable is independent

of all potential values of the mediating and outcome variables, and b) the mediating

variable is independent of all potential outcomes (Imai et al., 2010). That is, there should

be no identifiable pathway through which observed outcomes could impact mediating or

treatment variables, and also no pathway through which mediators could foreseeably

impact treatment variables. This study includes two mediation analyses, in both of which

the 2006 rainfall differential serves as a treatment variable. None of the observed

mediators or outcomes, migration, protest, and casualties, would be able to impact past

rainfall, thus meeting part a) of the sequential ignorability assumption. In order to meet

part b) of the sequential ignorability assumption, mediating variables and outcomes are

staggered in time. That is, protest outcomes take place two years after the migration

trends analyzed, and documented casualties are tracked solely after the political protest

events that precede them. The mediation analyses conducted are described in further detail below.

Mediation 1: Protest

The linear regression and probit models were combined to conduct a causal mediation analysis. The purpose of this analysis was to determine to what extent drought had a direct impact on protest occurrence versus to what extent its impact was indirect, through its influence on migration. This mediation analysis takes the linear regression of population growth on other factors as its first stage model and the probit regression as its second stage model. In the mediation analysis, 2006 rainfall differential functions as a treatment variable, while the first stage outcome, drought period population growth, serves as the mediator between drought and protest occurrence. Due to complications arising from the presence of a continuous treatment variable in combination with other factors in this model, sensitivity analysis was not performed as a follow-up. The R code outlined in Appendix II illustrates the method used.

Mediation 2: Casualties

One may also want to gain a better sense of how the presence of drought impacted protest outcomes in terms of its impact on violent conflict. Undoubtedly, the Syrian government's brutal crackdown on protesters was a primary reason Syria's protests became violent and escalated into its present civil war (Rodgers, Gritten, Offer, & Asare, 2016). However, policy planners may be interested in the extent that environmental factors lead to violent conflict in the presence of authoritarian regimes, and thus act as one of the precipitators of war.

For this reason, I again ran causal mediation analysis with rainfall as the treatment. In this analysis, the previously used probit model linking drought and migration to protest served as the first stage regression. The second stage model regressed deaths against the occurrence of protest, the log of the total population in 2010, and the early drought period rainfall differential. In this analysis, protest occurrence served as the mediating variable. Sensitivity analysis was also conducted for this model. The R code used to conduct this analysis is detailed in Appendix III.

Chapter III

Results

My analysis confirmed that links indeed exist between Syria's drought crisis, its subsequent internal migration and resulting sociopolitical instability, and its ongoing conflict. Drought appears to have led to internal migration. People appear to have fled agricultural areas impacted by drought, moving to cities and areas that were less hard-hit. Syria's 2011 protest locations correlated both with subdistricts that received significant influxes of people and subdistricts that were impacted by drought. This result suggests that drought increased the likelihood of protest both locally, through its direct impact on farmers, and in other locations, where its impact on protest was mediated by migration of people from one subdistrict to another. Because of the Syrian government's violent crackdown on protests, the occurrence of protest in a subdistrict significantly predicted the scale of the violence that followed, as measured by the number of civilian deaths directly caused by the ongoing conflict. Through this causal pathway, drought increased the likelihood of protest in a given subdistrict and thus the scale of the loss of life that followed.

The greatest value to have come out of this analysis, however, is not the fact that climate impacts such as drought are linked to increased instability and conflict, or even the role that migration plays in linking drought to conflict. It is the ability to determine, at the subnational level, in what types of locations drought and sociopolitical instability are most closely linked. Mapping Syria's environmental and population factors revealed the

existence of three different areas in which subdistricts could be grouped together according to shared characteristics. Out of the three subregions studied, only the first, an ecologically rich area supporting substantial rainfed agriculture and high population densities, showed strong direct links between drought, outbound migration, and local protest. It is in this type of location where environmental peacebuilding interventions would likely have achieved the greatest impact. In the next subsection and those that follow, I describe how the analyses conducted came to these conclusions, from the cluster analysis, to the linear and probit regressions, to the mediation analyses that put existing correlations together into clear causal pathways.

Cluster Analysis

The cluster analysis results suggested that Syrian subdistricts can be grouped fairly naturally into three different clusters based on differences in the five factors analyzed. The emergence of these three clusters appears to be due to differences in landscape type; that is, the difference is climatological. The first cluster consists of land with lush vegetation, as indicated by high NDVI values. These areas are both densely populated and used for intensive agricultural production. Most of these areas form a crescent along Syria's western border, which has a warm Mediterranean climate. This fertile agricultural zone spans from parts of the northernmost governorate, Al Hasakah, to the southernmost governorate, Daraa.

The second cluster consisted of locations with less lush vegetation supporting less intensive agriculture and lower population densities. It appears to correspond closely to steppe land where scattered agriculture and nomadic herding are common. The third cluster corresponds to Syria's desert, which is sparsely populated and supports little

agriculture. It is located along Syria's eastern border, which the country shares with Iraq

and Jordan. Figure 10 illustrates these three subdistrict clusters, highlighting their

correspondence with the factors analyzed, including NDVI, cropland percentage, and

population density. Table 1 further illustrates the differences between each of the three

groups by providing mean values, by cluster, for each of the factors analyzed.
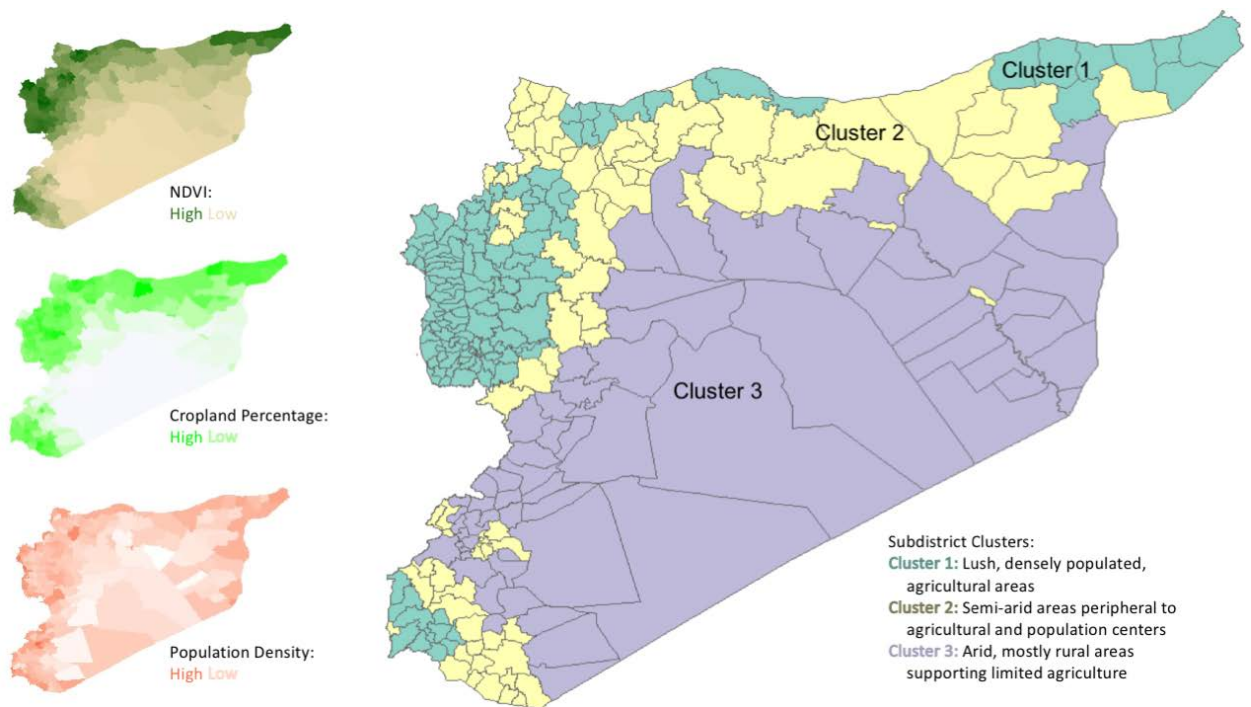
Figure 10. Cluster analysis outcome.

*Three different clusters of subdistricts emerged from the analysis. Cluster 1 consists of
densely populated agricultural areas. Cluster 2 consists of semi-arid areas peripheral to
agricultural and population centers. Cluster 3 is arid and supports limited agriculture.
Clusters correlate closely with differences in NDVI and, relatedly, the percentage of
cropland in each subdistrict devoted to agriculture.*

Table 1: Cluster analysis outcome: mean values of variables used, by cluster.

	Pre-Drought Vegetation (NDVI value)	Cropland Percentage (%)	Agricultural Proximity (% / km, x 10^{-2})	Closeness, 2006 (1 / km, x 10^{-6})	2006 Population Density (Log people / km^2)
Cluster 1	161	68.8	17.9	7.73	4.81
Cluster 2	111	61.3	12.1	7.12	4.79
Cluster 3	70.2	14.8	9.25	6.59	3.99

Note. Prior to the drought crisis, subdistricts in cluster 1 supported dense vegetation, intensive agricultural production, and high population densities. Subdistricts in cluster 2 supported less dense vegetation, less intensive agriculture, and lower population densities. Subdistricts in cluster 3 contained sparse vegetation, limited agriculture, and the lowest population densities of the three groups.

Based on the cluster analysis outcomes, one would expect Syria's drought to have the greatest impact on migration and protest in Cluster 1, a less significant impact in Cluster 2, and little to no impact in Cluster 3. The subsequent regression analysis confirms this is the case. Because many of Syria's agricultural subdistricts also support higher population densities, one might also expect not only rural-to-urban migration in the presence of prolonged drought, but also migration to similarly fertile areas that have been less hard-hit by the drought crisis. Linear regression analysis confirms this hypothesis and also indicates that the links between drought and migration were strongest in Cluster 1.

Regression Analysis

Two types of regression analysis were conducted. The first, a linear regression of the 2006-2008 population CAGR on population controls and environmental factors, confirmed that drought predicts migration in Cluster 1. The second analysis, a probit model regressing the occurrence of protest on drought, migration, and

52

environmental factors, confirmed that both drought and migration each independently predict protest occurrence.

Linear Regression: Population Growth Outcomes

As expected, a multiple linear regression analysis on the variables investigated showed that, when population and agricultural factors are controlled for, rainfall differential and historical drought significantly predict population migration trends. The correlation between rainfall, historical drought, and population growth was, as, expected, the strongest for agricultural zones and the weakest for desert areas. Within Cluster 1, every variable investigated showed a statistically significant relationship with population growth from 2006 to 2008, including the interaction term between historical drought and agricultural proximity. These relationships are shown in Table 2.

While investigating these relationships, a number of methods were used to ensure the data were relatively normal, relationships under analysis were indeed linear, and any heteroscedasticity or clustering was limited. These included analyses of residuals versus fitted values, residuals versus leverage, and QQ and scale-location plots, as well as graphical exploration using a generalized additive model. All variables investigated were free from noticeable heteroscedasticity and clustering, and exhibited linear relationships except for historical drought, which was then analyzed with this information in mind. The primary variable of interest, the 2006 rainfall differential, shows a strong positive linear relationship with population growth across Cluster 1 subdistricts, as illustrated in Figure 11.

Table 2: Population CAGR (2006-2008) regressed on environmental and population factors.

	Cluster 1	Cluster 2	Cluster 3	All Subdistricts
Logged Population Density, 2006	-0.238 ***	-0.259 ***	-0.244 ***	-0.243 ***
	(0.0211)	(0.0338)	(0.0344)	(0.016)
Closeness, 2006	105,000 **	139,000 ***	636,000	130,000 ***
	(32,600)	(30,800)	(49,100)	(17,400)
Rainfall Differential, 2006	0.00173 ***	0.00179	0.000946	0.00145 **
	(0.000409)	(0.00182)	(0.00332)	(0.000497)
Historical Drought	-0.0602 ***	-0.212 *	0.0222	-0.00904
	(0.0168)	(0.0961)	(0.0567)	(0.013)
Percentage Agricultural Land	0.00571 *	0.00751 *	0.00238	0.00313 **
	(0.00238)	(0.00355)	(0.00433)	(0.000977)
Agricultural Proximity	-10.8 ***	-60.1 *	-10.4	-4.37
	(2.68)	(25.6)	(17.4)	(2.36)
Population CAGR, 1990-2000	0.247 **	-0.065	-0.447 *	0.031
	(0.0813)	(0.126)	(0.175)	(0.067)
Interaction: Historical Drought and Agricultural Proximity	0.403 ***	1.75 *	0.288	0.15
	(0.0851)	(0.749)	(0.552)	(0.0766)
R-squared	0.762	0.579	0.577	0.579
F-statistic	45.33	12.58	9.199	44.42
Degrees of Freedom	113	73	54	258
p-value	***	***	***	***

Note: $* = p < 0.05$, $** = p < 0.01$, $*** p < 0.001$.

All environmental and population factors investigated are found to be significant in cluster 1. In cluster 2 subdistricts, which support less rainfed agriculture, the 2006 rainfall differential ceases to be significant; however, other factors such as proximity to agriculture and population centers remain important. In cluster 3 subdistricts, which are primarily arid, only the population density and growth rate remain significant. These disparities suggest links between climate impacts and migration are strongest in locations with properties similar to those subdistricts in cluster 1.
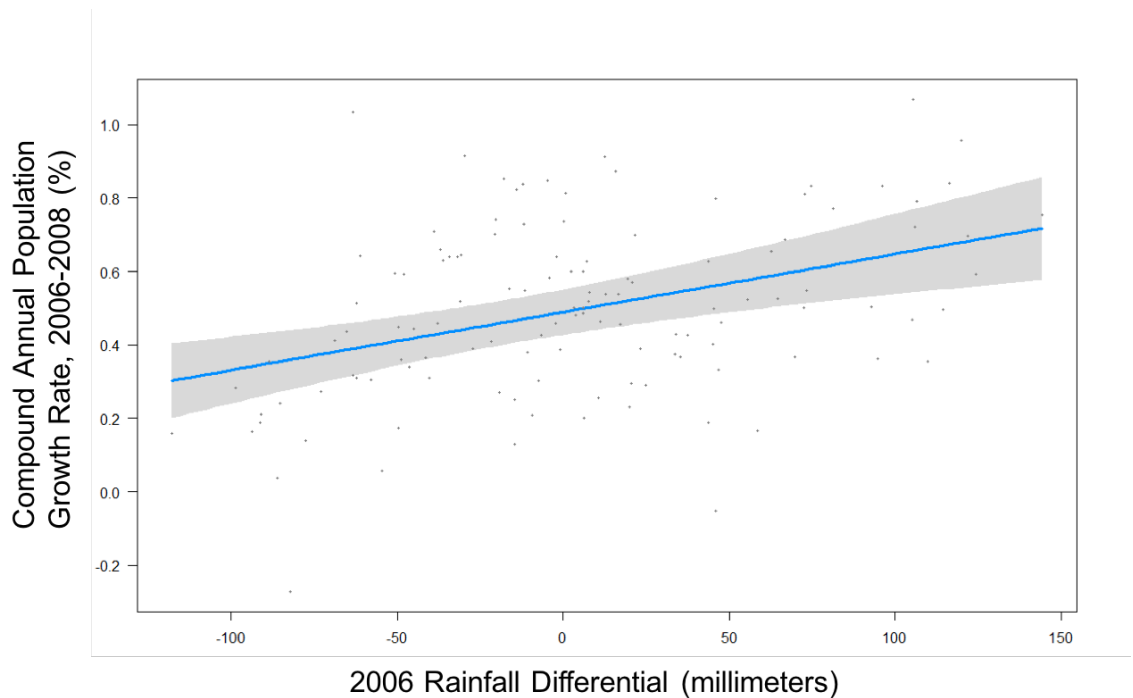
Figure 11. Population growth versus 2006 rainfall differential.

Note that the 2006 rainfall differential is the number of millimeters of precipitation in 2006 above the national pre-drought average. The grey band here represents the 95% confidence interval. The relationship displayed here is for the regression of population growth on rainfall in Cluster 1 subdistricts.

Analysis indicated significant clustering of historical drought data. This is likely due to the fact that data on historical drought are averaged over hydrological catchments that span multiple subdistricts. For this reason, I additionally explored the interaction between agricultural proximity, historical drought, and population growth by regressing the 2006-2008 CAGR on agricultural proximity under different historical drought domains, while controlling for all of the variables included in the original regression analysis. Results of this exploration are illustrated in Figure 12. The relationship between population growth and proximity to agricultural areas varied in sign depending on historical drought intensity. The overall trend is dominated by the impact of severe

drought on the relationship between drought and migration: Subdistricts near agricultural

centers experience significantly higher population growth when the area as a whole is

historically prone to drought.
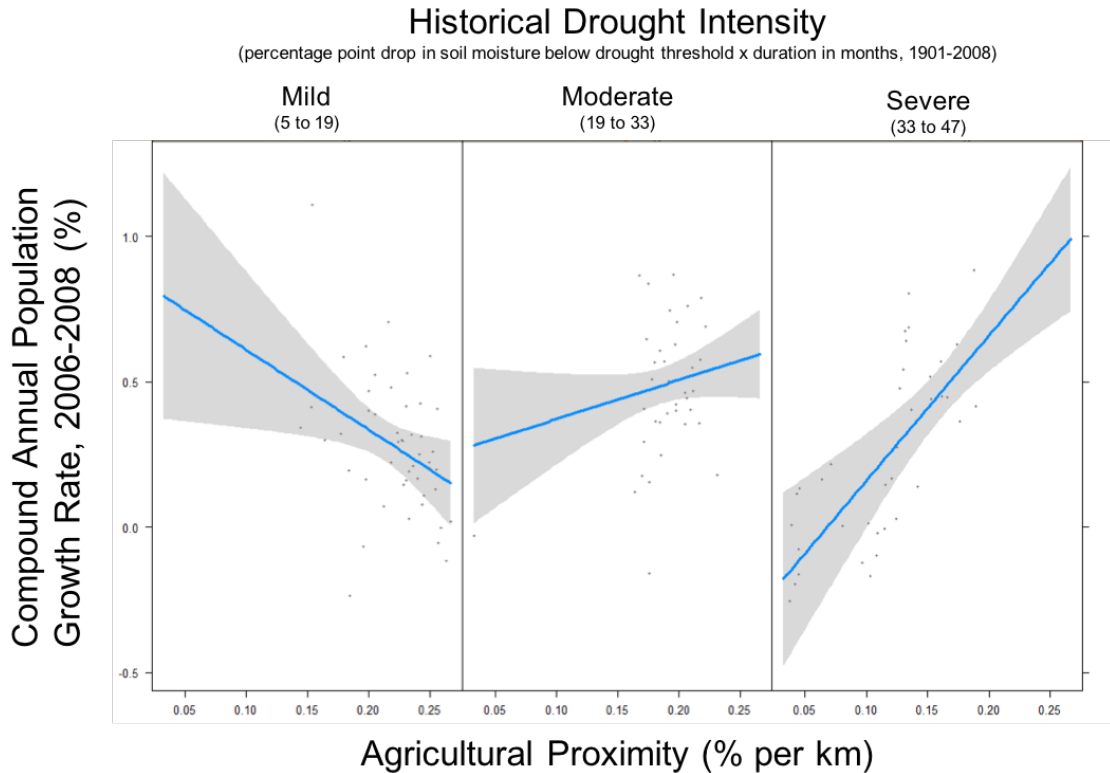
Figure 12. Variation in population migration trends by historical drought intensity.

*Here, drought intensity represents the percentage point drop in soil moisture below the
threshold for drought identification, multiplied by the duration of the drought in months.
Drought is here defined as a continuous period in which soil moisture remains at least
20% below its normal value. This graph is an additional representation of the linear
regression of population CAGR on environmental and population factors explored
previously. Here, breaking down the relationship between population growth and
agricultural proximity based on the intensity of historical drought reveals nonlinear
trends, with a strong linear relationship emerging only in areas that have historically
experienced severe drought. The relationship displayed here is for the regression of
population growth on agricultural proximity in Cluster 1 subdistricts.*

This exploration revealed that the strongest link between population growth and proximity to agricultural lands occurred in areas that have historically been most prone to drought. One may infer that the link between population growth and proximity to vulnerable populations is indicative that the population growth is in fact related to migration. Regression results would then suggest that migration-related growth is most likely in drought prone areas. One possible explanation for this relationship is that groundwater reserves are likely to be limited in drought-prone regions, leaving farmers with fewer options when drought strikes. Another possible explanation is that families in drought-prone regions may be more open to migration as needed based on crop conditions.

Probit Regression: Protest Outcomes

A probit regression of protest data on four factors, the log of each subdistrict's 2010 population, its drought-period population growth rate, its 2006 rainfall differential, and the intensity of historical drought in the area, revealed that both the decreased rainfall during Syria's drought crisis and resulting differences in population growth rates significantly predicted the occurrence of protest. Once again, these factors were most significant in Cluster 1 subdistricts. In particular, the 2006 rainfall differential remained significant only for Cluster 1 subdistricts, indicating that the immediate drought crisis independently predicted the occurrence of protest apart from its impact on migration only in locations that supported significant agriculture. The results of this analysis are shown for each cluster in Table 3. Additionally, graphical relationships are shown for Cluster 1 subdistricts in Figure 13.

Table 3: Probit Regression of Protest Occurrence on Environmental and Population
Factors.

	Cluster 1	Cluster 2	Cluster 3	All Subdistricts
Population CAGR, 2006-2008	1.56 **	0.914 *	1.19 *	0.922 ***
	(0.484)	(0.384)	(0.547)	(0.245)
Rainfall Differential, 2006	-0.00721 *	0.0132	-0.0179	-0.00390
	(0.00357)	(0.00819)	(0.0109)	(0.00244)
Historical Drought	0.0573 *	-0.108 *	-0.152 *	0.00881
	(0.0231)	(0.0482)	(0.0711)	(0.0148)
Logged Total Population, 2010	0.834 ***	0.510 **	0.560 **	0.556 ***
	(0.201)	(0.173)	(0.210)	(0.0987)

Note: * = $p < 0.05$, ** = $p < 0.01$, *** $p < 0.001$.

Both drought period population growth and drought factors are found to be statistically significant
predictors of protest occurrence for subdistricts in cluster 1. In clusters 2 and 3, where land is more arid,
protest occurrence appears to be decoupled from the 2006 rainfall differential, suggesting that drought
impacts are linked more directly to protest in locations that depend heavily on rainfed agriculture.

As expected, this analysis confirmed a positive relationship between population

growth, our indicator for migration between subdistricts, and the occurrence of protest.

Additionally, both the historical drought intensity and the 2006 rainfall deficit

significantly predicted protest occurrence. The relationship between protest and 2006

rainfall appears negative because increases in rainfall were negatively associated with

protest. As expected, our population control variable, the log of the total population in

2010, was significantly positively associated with protest occurrence. Figure 13 illustrates

these relationships.
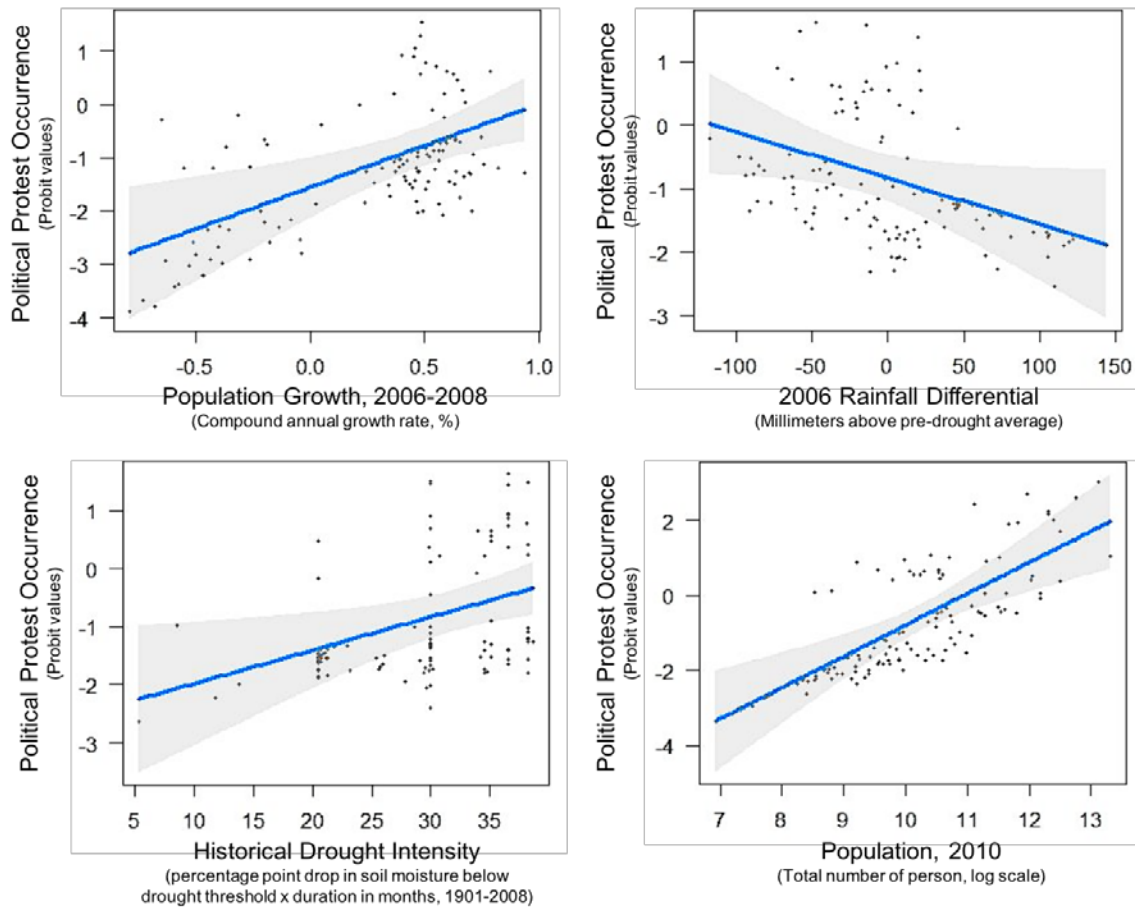
Figure 13. Probit regression of political protest occurrence on environmental and population factors.

Protest occurrence in each subdistrict was regressed on the 2006-2008 population growth rate, the 2006 rainfall differential, the historical drought intensity, and the log of each subdistrict's 2010 population. The grey band here represents the 95% confidence interval. Relationships shown are for Cluster 1 subdistricts.

Causal Mediation Analysis

To investigate the causal chain linking drought, migration, protest, and subsequent loss of life, two causal mediation analyses were conducted. The first, which combined the previously discussed linear regression and probit models, showed that drought significantly impacted the likelihood of protest occurrence both through as a proximate cause and through its impact on population migration, which served as a

mediating variable. The second mediation analysis combined the probit model discussed above with a second model regressing civilian deaths on protest, the 2006 rainfall differential, and the total population. This second stage mediation analysis showed that the impact of drought on the subsequent scale of violence was mediated entirely by protest, that is, drought increased the likelihood of protest, which in turn was predicted the number of subsequent civilian casualties in the subdistrict.

Mediation 1: From Drought to Migration to Protest

In the first causal mediation analysis, the 2006 rainfall differential served as a continuous treatment variable, while the population growth from 2006 to 2008 served as a mediating variable. Due to the presence of a continuous treatment variable, and the fact that mediation analysis inherently describes the impact of moving from a control to a treatment group, intuitive control and treatment values for the 2006 rainfall differential were identified and used in the analysis. A rainfall differential of -57.1 mm, or one standard deviation below the pre-drought average, was used for the control value, while a rainfall differential of zero, or precipitation equal to the pre-drought average, was used for the treatment value. Mediation analysis was then conducted on Cluster 1 subdistricts.

As expected from the preceding analysis, differences in rainfall impacted the likelihood of protest though both directly and indirectly, through its impact on population migration. The results were statistically significant. As expected, low rainfall directly increased the likelihood of protest in a given area. Additionally, low rainfall impacted population migration, increasing the likelihood of protest in less drought-prone areas through its impact on population growth rates. Results were similar in both control and treatment groups; however, the impact of migration on protest was larger in subdistricts

that simultaneously experienced drought. Mediation analysis results are shown in Table 4 and Figure 14.

Table 4: Causal mediation analysis: From drought to migration to protest.

	Average Impact across all subdistricts	Normal Rainfall 2006 rainfall = pre-drought average	Low Rainfall 2006 rainfall = 1 SD below pre-drought average
Average Mediated Effect	0.0302 **	0.0273 **	0.0331 **
Confidence Interval	(0.01, 0.06)	(0.01, 0.05)	(0.01, 0.06)
(Drought → Migration → Protest)			
Average Direct Effect	-0.106 **	-0.109 **	-0.103 **
Confidence Interval	(-0.20, -0.03)	(-0.20, -0.03)	(-0.20, -0.03)
(Drought → Protest)			
Proportion Mediated	-0.398 †	-0.360 †	-0.437 †
Confidence Interval	(-3.52, 1.14)	(-3.35, 1.14)	(-3.69, 1.15)
Total Effect	-0.0757 †		
Confidence Interval	(-0.18, 0.00)		

Note. † = $p < 0.06$, * = $p < 0.05$, ** = $p < 0.01$.
Sample size = 122 subdistricts.

Confidence intervals were obtained through nonparametric bootstrapping with the percentile method over 1,000 simulations. 2006 rainfall differential served as a continuous treatment variable. For ease of reporting, normal rainfall, defined as a 2006 rainfall differential of 0 mm, was assigned as the treatment, while low rainfall, equal to a 2006 rainfall differential of -57.1 mm, or one standard deviation below the pre-drought average, was assigned as the control. As expected, higher rainfall is negatively associated with protest occurrence via a direct pathway, but positively associated with protest through its impact on migration. The impact of migration on protest was larger in subdistricts that simultaneously experienced drought.
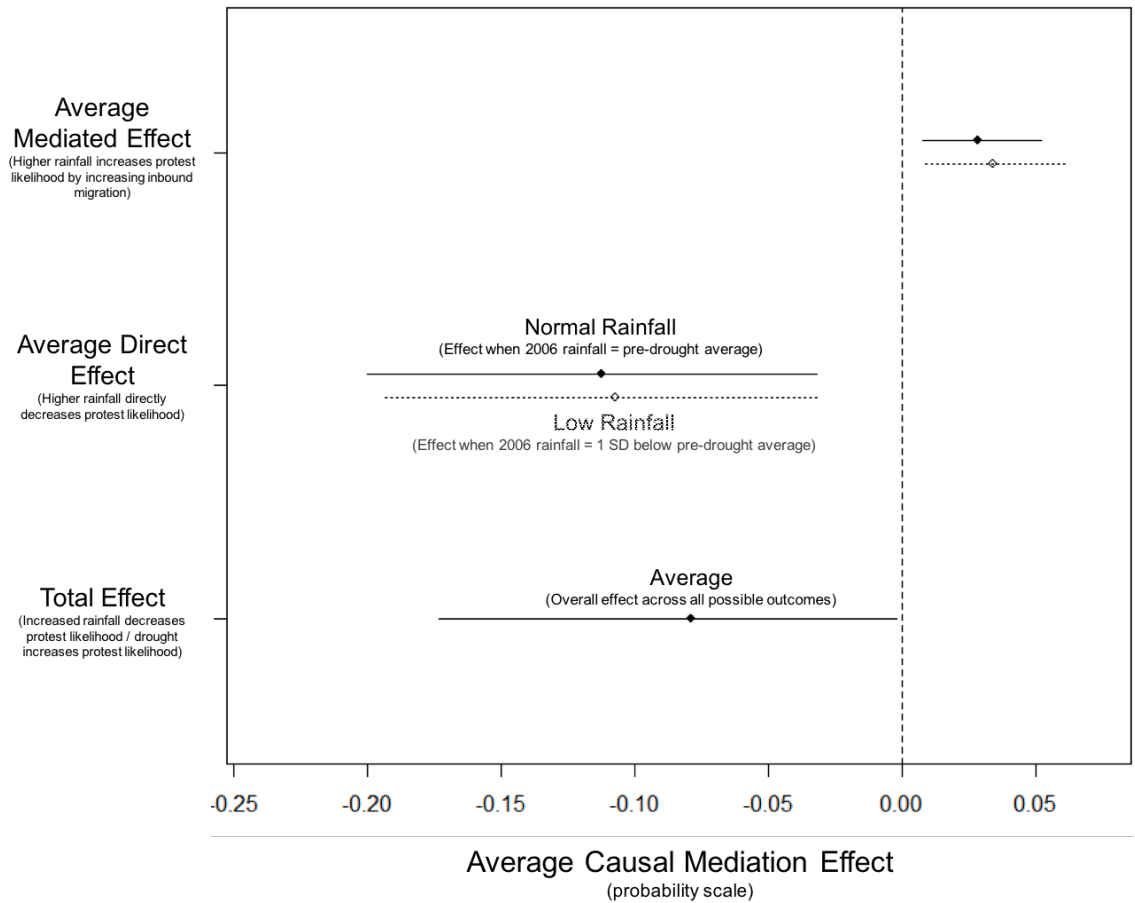
Figure 14: Causal mediation analysis: From drought to migration to protest.

Normal rainfall, as compared to drought conditions, directly decreases the likelihood of protest occurring in a given subdistrict. However, in the presence of drought elsewhere, protests also become more likely in subdistricts with normal levels of rainfall due to increases in inbound migration.

These results are important because they reveal that the impact of long-term drought on sociopolitical instability may be masked by migration trends. In order to determine the true impact of drought-induced instability, it is important to account for mediated effects. A passing glance at the mediation analysis results might initially suggest that the mediated effect of drought on sociopolitical instability is indistinguishable from zero. However, this result simply compares locations with low

rainfall to those with high rainfall during the same period. Drought reduces population growth in low rainfall areas by triggering migration to areas that are not experiencing drought. Thus, migration increases the likelihood of protest in areas with higher rainfall as well, resulting in a significant net increase in sociopolitical instability whose total impact would be masked through an analysis of local impacts alone. The challenge then becomes determining to what extent drought impacts sociopolitical stability, in what locations, and how to prevent drought crises in crucial areas from escalating into larger conflicts.

One way to determine true impact of drought is by tracing the chain of events and determining the impact of each event along the way. First, in the presence of drought, populations migrate to less drought prone areas. If the drought had not occurred, zones that experienced above average rainfall would not have experienced increases in their population growth rates as a result of inbound migration. This inbound migration impacted the likelihood of protest. Thus, the positive association between above average rainfall and protest was a direct result of drought elsewhere. The direct effect shown above illustrates a link between increased rainfall and reduced likelihood of protest. Because a linear relationship is assumed, this is equivalent to the statement that reduced rainfall directly increases the likelihood of protest. Putting these two effects together clarifies overall impact of rainfall on protest likelihood both locally and in surrounding areas.

Note that, while sensitivity analysis is an important component of mediation analysis, it could not be conducted for this particular model. The current mediation package is not designed to accommodate the presence of a continuous treatment variable,

which in combination with other factors inherent in this particular model, prevented

sensitivity analysis from running properly. Sensitivity analysis is important because it

helps to identify the degree to which assumptions such as sequential ignorability must be

violated for the conclusions of a given analysis to be reversed (Imai, et al., 2010). Given

the causal independence of Syria's 2006 rainfall levels, it is likely that sequential

ignorability holds for this particular mediation model. Subsequent models, however,

should attempt to implement sensitivity analysis wherever possible to determine to what

extent the broader conclusions of this model continue to hold.

Mediation 2: From Drought to Protest to Casualties

The second causal mediation analysis also was conducted on Cluster 1

subdistricts, using the 2006 rainfall differential as a continuous treatment variable. In

order to better understand the impact of varying levels of drought on protest and thus the

subsequent scale of violence, it was conducted twice using two different control and

treatment values. In both case, the treatment value was a 2006 rainfall differential of zero,

or normal rainfall levels. In the first analysis, the control value was assigned as a rainfall

level of one standard deviation below the pre-drought average, while in the second

analysis, the control value was assigned as a rainfall level of two standard deviations

below the pre-drought average. In both cases, no difference emerged between "treatment"

and "control" groups, and the effect of drought on casualties was partially mediated by

the occurrence of protest.

Through its influence on protest occurrence, drought increased the number of

subsequent deaths by making political protests more likely. Severe drought had roughly

double the impact of moderate drought on the scale of violence following protests, all

other factors being equal. Absence of drought, that is, normal to increased rainfall, also increased the number of expected number of deaths in a given subdistrict via an unknown pathway. This increase in deaths in areas of higher rainfall may have occurred as a result of migration impacts or fighting over remaining arable farmland and grain stores in these areas. Because these causal pathways produce opposite impacts on the number of expected casualties in each subdistrict, the net effect of rainfall variation on conflict-related casualties appears neutral. Mediation analysis, however, reveals that this apparent neutral impact is the result of multiple competing causal pathways, all of which may have functioned to increase the number of violent deaths in different locations. The relationships for both drought scenarios are illustrated in Table 5 and Figure 15.

Table 5: Causal mediation analysis: From drought to protest to confirmed civilian deaths.

	Moderate Drought	Severe Drought
Treatment: 2006 Rainfall Level =	Pre-drought average	Pre-drought average
Control: 2006 Rainfall Level =	1 SD below pre-drought average	2 SDs below pre-drought average
Average Mediated Effect	-3.118 [†]	-6.458 *
Confidence Interval	(-6.72, 0.00)	(-13.20, -0.99)
(Drought → Protest → Violent Deaths)		
Average Direct Effect	3.033 *	6.056 *
Confidence Interval	(0.52, 5.97)	(0.77, 11.86)
(Drought → Violent Deaths)		
Proportion Mediated	36.859	16.046
Confidence Interval	(-16.59, 18.09)	(-38.77, 20.44)
Total Effect	-0.085	-0.402
Confidence Interval	(-4.78, 4.16)	(-8.31, 7.87)

Note. [†] = $p < 0.06$, * = $p < 0.05$.

Sample size = 122 subdistricts.

No variation was found between treatment and control groups, so average effects are reported for each drought scenario. Confidence intervals were obtained through nonparametric bootstrapping with the percentile method over 1,000 simulations. 2006 rainfall differential served as a continuous treatment variable. The number of confirmed civilian deaths, while mediated entirely by the occurrence of protest, is impacted by drought. The negative average mediated effect indicates that subdistricts with lower rainfall were more likely to experience political protests and, due to the regime's brutal crackdown, accompanying loss of life. The positive direct effect indicates subdistricts with higher rainfall also directly experienced an increase in deaths through another pathway, possibly outbound migration or fighting over remaining arable farmland and grain stores.
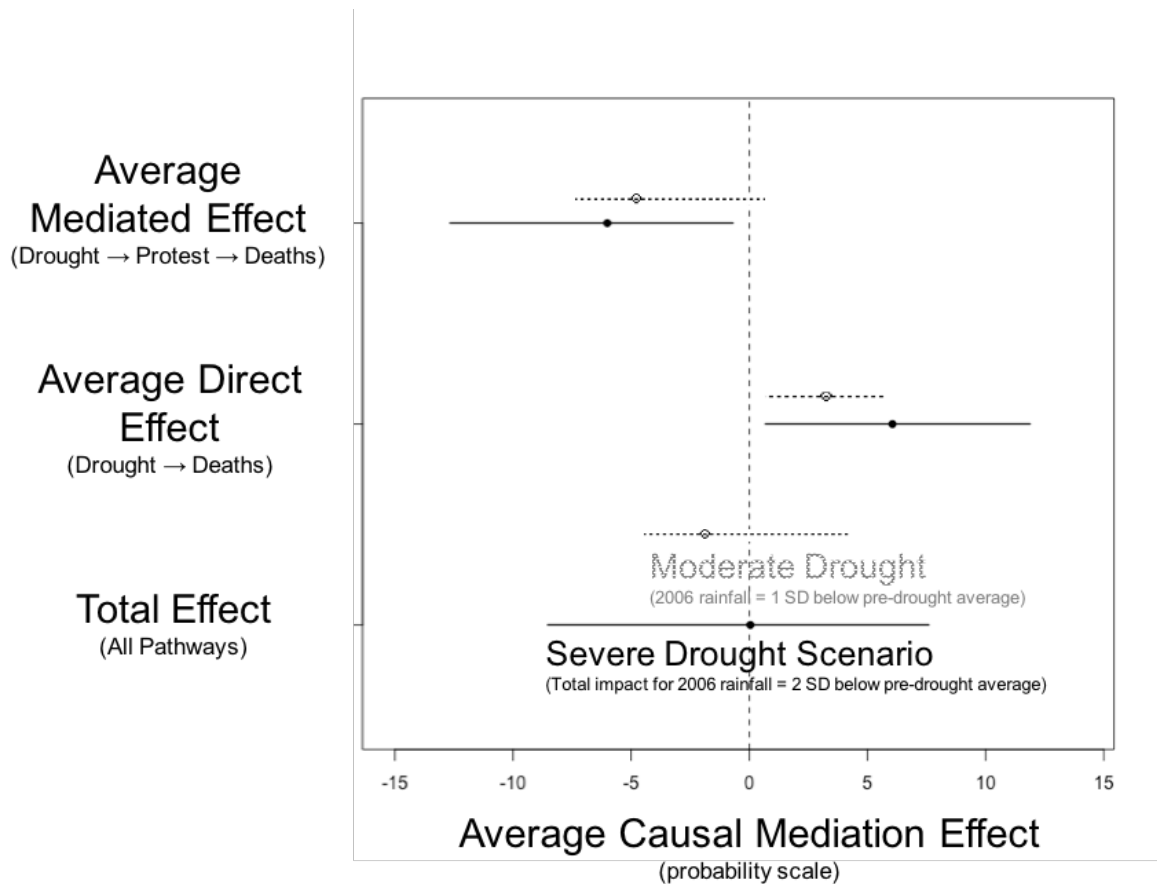
Figure 15: Causal mediation analysis: From drought to protest to civilian deaths.

Two scenarios are shown, the difference between severe drought and normal rainfall, and the difference between moderate drought and normal rainfall. In both cases, no variation was found between treatment and control groups, so average effects were reported. The effect of drought on the number of confirmed civilian deaths was mediated partially through protest occurrence. The negative average mediated effect indicates that subdistricts with lower rainfall were more likely to experience protest and, following violent regime suppression, an increase in violence and civilian casualties. The positive direct effect indicates that subdistricts with higher rainfall also experienced an increase in deaths through another pathway, possibly impacts of migration or fighting over remaining arable farmland and grain stores.

A follow-up sensitivity analysis, however, suggests that these results are inconclusive. A value of $\rho = 0.95$ was obtained, whereas the average mediated effect becomes indistinguishable from zero at $\rho = 0.8$. The implication of this result is that this

second mediation analysis is sensitive to potential violations of the sequential ignorability

assumption. This means that a small unobserved cofounder could potentially overturn

conclusion obtained under sequential ignorability. Results of the sensitivity analysis

conducted are shown in Figure 16.
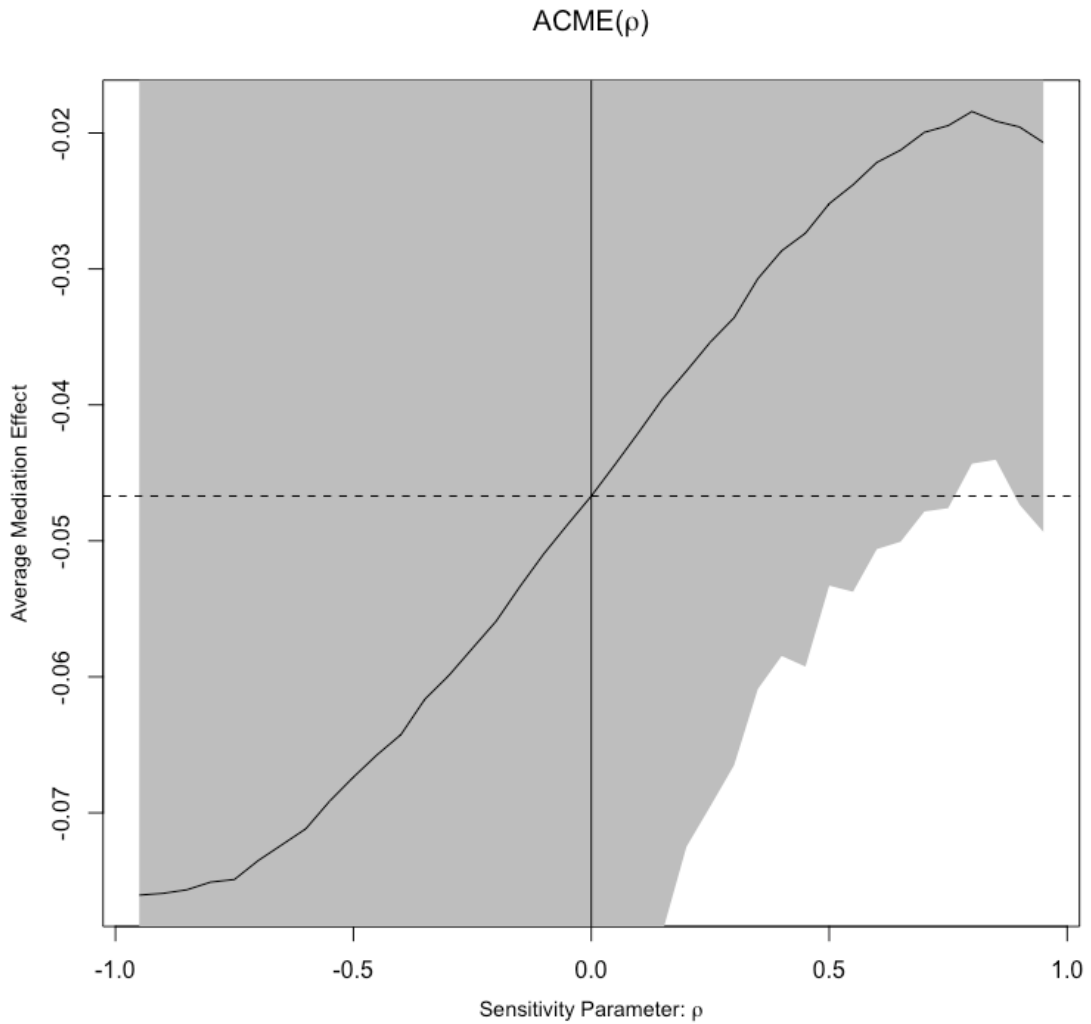
Figure 16: Sensitivity analysis: From drought to protest to civilian deaths.

Sensitivity analysis suggests that causal mediation results linking drought to civilian deaths are inconclusive. Analysis yielded a value of $\rho = 0.95$, whereas the average mediated effect becomes indistinguishable from zero at $\rho = 0.8$. This result implies that the analysis is sensitive to potential violations of the sequential ignorability assumption, indicating that a small unobserved cofounder could potentially overturn its conclusions.

Conclusions

These analyses illustrate a causal pathway between drought, migration, protest, and subsequent civilian casualties. Drought predicted both migration between subdistricts and the occurrence of protest. Much of the impact of drought on protest likelihood was mediated by migration, showing that, when both direct and mediated effects are considered, the impact of drought on sociopolitical instability was much greater than may have otherwise been inferred. Additionally, drought may have impacted the scale of violence in each subdistrict during the subsequent civil war through its impact on whether or not initial protests occurred in a given area. Most importantly to future conflict prevention efforts, however, the causal relationship between drought, migration, and subsequent sociopolitical instability maintained significance only in Cluster 1 subdistricts, those supporting significant amounts of rainfed agriculture and high population densities. Potential locations for future environmental peacebuilding efforts may thus be identified using methods similar to those employed in the initial cluster analysis. Future use of this or similar methodologies may thus allow for improved efforts at preventing complex humanitarian emergencies and conflicts through proactive and precise targeting of environmental peacebuilding efforts at the subnational level.

Chapter IV

Discussion

This study succeeded in quantitatively validating reports that Syria's drought played a role in sparking its sociopolitical instability. The study further showed that internal migration at the subdistrict level played a significant role in mediating the relationship between drought and protest occurrence. Additionally, the study established a link between drought intensity and the scale of violent conflict once protests begin and violent suppression have occurred. In addition to validating existing narratives around the role of drought in shaping the Syrian conflict, the study produced results that may be helpful for more effectively targeting future environmental peacebuilding work. Testing the variable relationships on different clusters of subdistricts helped to types of location links between drought and conflict. Results suggested that areas heavily dependent upon rainfed agriculture, that support high population densities, and that are relatively near urban centers are particularly vulnerable to experiencing outbound migration capable of destabilizing nearby urban centers in the presence of drought and food scarcity.

A serendipitous finding in this study was that migration actually occurred quite quickly in the presence of drought, within the first two years of the onset of major drought. This is inconsistent with an expected two-year delay based on the UNFAO country study. There may be many reasons for this finding. The fact that geographic closeness and agricultural proximity were significant factors in determining whether a given subdistrict experienced inbound migration during the drought suggests people tend

to migrate shorter distances when possible. In Cluster 1, in which these relationships were most significant, subdistricts are close enough together that it would have been quite reasonable for one or more family members to have migrated to cities looking for work intermittently while still ensuring farms were taken care of at home. This type of migration is likely to have been included in population counts by LandScan since the dataset's calculations incorporate multiple signs of increased economic activity such as changes in nighttime illumination, not just new dwellings. Such a view is consistent with UNFAO predictions, which stated that families had been supplementing their income through alternative means when crop outputs were low, prior to abandoning their fields altogether.

Other explanatory factors might include potential algorithm changes in LandScan's population estimates after 2008, the impact of efforts by UNFAO in-country teams to provide agricultural aid and reduce migration beginning in 2008, or changes in migration decisions due to the impact of 2008 economic factors on cities. Regardless, the study's results suggest that migration did occur; that it occurred early in the drought crisis, before the scale of the crisis could be measured and international aid requested; and that this early migration played a mediating role in the relationship between drought and protest in Syria. These unsettling implications highlight the importance of targeted, proactive environmental peacebuilding work in areas susceptible to climate impacts, particularly in locations with limited government capacity to cope with resulting changes and other underlying risk factors for sociopolitical instability.

While the study does provide valuable insights for future work, it includes a number of limitations that will need to be overcome to before its line of research is used

to target potential areas for environmental peacebuilding work. First, and perhaps most obviously, the geography of the present study is restricted to Syria. Future research should ideally build on the datasets used, many of which are global in nature, select appropriate units of analysis capable of spanning nations, and combine these with additional information on sociopolitical instability and conflict to better understand to what extent the results are globalizable. I made some attempt to study global factors quantitatively in the course of this study and found the task required more time and resources than were presently available. However, the required data are available and should be studied as quickly as possible to build future models that may help guide environmental peacebuilding work. Expanding the study to a global scale will require taking into account additional environmental information that may be relevant in some locations, such as the presence of temperature spikes. Selecting datasets to use as indicators of instability and conflict that enable modelling at subnational levels while still remaining relevant across country contexts will be an additional and important challenge.

Future studies should also make attempts to overcome a number of additional limitations inherent in this study. First, it will be important to ensure that future users of cluster analysis in tandem with regression take steps to account for the impact that the use of multiple groupings has on p-values. Additional checks for heteroscedasticity and methods to account for it in interpreting and reporting results should also be employed. Sensitivity analysis should also be used, when possible, to determine how robust mediation analyses are to modeling assumptions. As evidenced by the technical difficulties encountered during this study when implementing sensitivity analyses to

complement mediation, researchers attempting to perform mediation analyses similar to those used in this study should attempt to implement sensitivity analysis as a first step.

Based on my analysis of Syria, I would expect links to appear between conflict and environmental risk factors in a number of other countries as well. The locations within Syria that appeared most vulnerable to protest were those that were densely populated and agriculturally productive, in regions with dense natural vegetation and high rainfall in past years, but also past histories of drought. These types of hotspots for sociopolitical instability are important areas to examine in regions facing increasing water stress and desertification. Similar types of locations worldwide currently experiencing drought-related desertification have already been impacted by instability and conflict. According to research by the UN Desertification Convention, severe land degradation is now impacting 168 countries across the world (King, 2013). Many of these nations are in the MENA region, and similar studies probing instability and conflict at the subnational level would likely find similar types of hotspots across nations.

In fact, recent reports of drought and desertification-related instability and conflict across the MENA region, even in democratic nations, appear to support this hypothesis. Among these nations is Sudan, where increasing desertification has already been a source of conflict in Darfur (UNEP, 2007). In Mali, increasing desertification over the past decade contributed to the development of armed conflict in 2012, stalled peace accords, and the country's present humanitarian crisis (Bunting, 2010; Human Rights Watch, 2017). Water scarcity contributed to instability in many of the Arab spring nations, as discussed previously. Even Tunisia, the only Arab Spring nation to have transitioned from its state of instability to a successful democracy, continues to experience water

stress and related discontent despite its successful democratic reforms (Keating, 2015; Pope, 2016).

Eleven nations are, according to UNICEF (n.d.), already in the grip of severe drought: Ethiopia, Eritrea, Somalia, Sudan, Uganda, Afghanistan, Iran, Morocco, Pakistan, and large portions of India and China. Over 100 million people have been impacted, and many of whom face food insecurity and, in some nations, possible starvation. A massive multi-national effort will be necessary to prevent multiple humanitarian crises in these locations within the next few years. In order to prevent losses of life in the millions, possible large-scale refugee movements and conflicts within the next decade, funding and assistance intervening will need to be committed within the next year. Due to the present state of the U.S. government and its relevant agencies, possibly the only major, well-resourced organization in the nation capable of cooperating internationally to prevent these outcomes is the US military.

Even given significant assistance, initial targets for both humanitarian aid and environmental peacebuilding interventions must first be identified. Doing so will require additional urgent research that may build on the analyses and conclusions presented with this study. Once the factors linking drought to instability and conflict in Syria have been confirmed alongside additional contributing factors at the global level, these factors will need to be further explored to determine their appropriate weights in models predicting unrest and conflict. Outcomes of this work could then be used to identify critical areas for environmental peacebuilding interventions at a global level. This type of modelling and analysis will be critical to successfully targeting funding and interventions over the next several years.

Once this additional research has been conducted and areas for intervention identified, pilot studies will be helpful to determine the effectiveness of environmental peacebuilding efforts. Interventions are urgent in multiple locations, but funding is unlikely to allow for immediate action in all of the locations. In response to this challenge, a randomized controlled trial employing matching techniques across locations could be conducted to evaluate and improve the efficacy of environmental peacebuilding efforts in the future. This type of methodology is already in use by organizations such as the Abdul Latif Jameel Poverty Action Lab (2010) to evaluate the efficacy of poverty alleviation interventions. These peacebuilding efforts may employ a variety of methods based on local needs, including food and agricultural aid (Saferworld, 2017), promoting sustainable land and water conflict resolution (UNFAO, 2016), water conservation infrastructure, agroecological methods for soil rehabilitation (Groundswell International, 2011), agricultural education and women's empowerment programs, renewable energy generation and transitions away from water-intensive fossil fuel plants (Union of Concerned Scientists, 2016).

An effective environmental peacebuilding study is likely to be of great interest to the U.S. military due to the potential to prevent both violent conflict and the spread of extremist groups who may be poised to take advantage of political instability (Holmer, 2013). Military support for peacebuilding pilot studies will likely also be necessary in cases where interventions take place in conflict-impacted locations. Assisting with interventions in conflict zones is likely also of military interest due to its ability to support existing community allyship and counterterrorism efforts. As noted in the

introduction, such tandem work has taken place successfully in Afghanistan (O'Connor, 2017; Martinez, 2017).

In cases where other military interventions are present, great care would need to be taken to ensure that their impacts on existing peacebuilding work are accounted for in studies of peacebuilding efficacy. Additionally, in order to ensure this critical work is able to take place both in a timely manner and at a scale necessary to prevent widespread instability, refugee movements, conflict, and increasing influence of extremist groups in conflict situations, a timely commitment of federal funding and support will be crucial.

An additional benefit of further work in this area is its ability to break the cycle of climate change and conflict. As evidenced by this study, Climate change and conflict exist in a feedback loop in which climate change induces conflict by increasing periods of water and food scarcity that can trigger migration and sociopolitical instability. Conflict, in turn, contributes to further climate change by directly increasing fossil fuel emissions; contributing to further land degradation, resulting in releases of soil carbon into the atmosphere; and using large amounts of federal funding that could otherwise be spent on climate mitigation efforts. Effective environmental peacebuilding work breaks this cycle both by helping reduce carbon emissions and by preventing conflict from arising due to climate impacts. The potential for environmental peacebuilding to prevent and reduce the scale of violent conflict has been discussed at length. Due to their importance in formulating policy interventions, methods of environmental peacebuilding that successfully reduce carbon emissions will be explored next.

Several methods of environmental peacebuilding are, even apart from their role in conflict prevention, among the most cost-effective methods of mitigating carbon

emissions and reducing lives lost due to the burning of fossil fuels. These methods include agroecological methods such as silvopasture and regenerative agriculture, replacing fossil fuel infrastructure with renewables, and educating women and girls while ensuring their participation in peacebuilding processes. A two-year study recently published in Hawken's *Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming* (2017) found these methods to be among the top ten most cost-effective climate mitigation solutions. If these methods are implemented at a large enough scale, in concert with other solutions, it may be possible to reverse the buildup of atmospheric CO_2 over the next thirty years.

Agroecological methods not only reduce the need for water, improve soil quality, and combat desertification, they also sequester large amounts of CO_2 back into the soil. Silvopasture does this by integrating trees into pasture land (Hawken, 2017, Silvopasture). Farmers are incentivized to participate in it due to the financial benefits provided by forestry products such as nuts, fruit, and mushrooms, as well as its ability to reduce the impact of drought on livestock and grazing land. Peer-to-peer education programs, such as those implemented in Afghanistan, have proven effective in spreading it.

According to recent estimates, at least 50 percent of sequestered soil carbon has been released due to land clearing and industrial agricultural practices (Hawken, 2017, Regenerative Agriculture). Regenerative agriculture returns this carbon to the soil, sequestering up to 60 tons per acre, by increasing carbon-rich soil organic matter. Doing so results in richer soil microbes needed for plant nutrient uptake, deeper roots, improved pest resistance, and greater overall water retention and soil fertility. Its practices include

no tillage, diverse cover crops, and multiple crop rotations. Farmers are financially incentivized to participate due not only to improvements in crop performance and drought resistance, but also to decrease in expenses for pesticides and synthetic fertilizers, which are not required or incorporated into regenerative agricultural practices. Like silvopasture, regenerative agricultural methods can be taught through peer-to-peer educational programs.

The most direct method of reducing fossil fuel emissions is that of replacing fossil fuel infrastructure with renewables. Doing so is also important for water conservation in drought-prone locations because fossil fuel use requires large amounts of water both for extraction and power plant cooling, averaging 95 liters per kilowatt-hour generated (Jones, 2008). In water-stressed locations that are rich in oil reserves, including several Arab nations, use of water for fossil fuel production has contributed to aquifer depletion, driving down agricultural production and forcing nations such as Saudi Arabia to become increasingly dependent on food imports (Polycarpou, 2011). Emissions, particularly those from burning coal, contribute to at least 1.4 million deaths annually (Fundación DARA Internacional, 2012), making efforts to phase out fossil fuel infrastructure in densely populated areas among the most cost-effective methods for reducing total human mortality available today (Batchelor, Miller, Iler, Houghstow, & Clark, 2017). In severely water-stressed and conflict-vulnerable locations, phasing out fossil fuel infrastructure and replacing it with distributed renewable energy generation saves critical water resources, reduces the vulnerability of energy infrastructure to conflict-related damages, and can contribute to income generation and community empowerment when accompanied by local skill training on construction and maintenance. *Drawdown* identifies on-shore wind

and solar as the two most cost-effective methods of renewable energy generation. Of these two, community solar is the faster to develop, requiring only a few months to install, and has seen increasing growth in capacity in developing nations (Spross, 2014).

Education of women and girls contributes both to conflict prevention through peacebuilding and climate change mitigation itself. Women with more years of education have fewer and healthier children, which reduces carbon emissions, water needs, and the population shocks that contribute to instability by stabilizing population growth (Hawken, 2017, Educating Girls). Educated girls contribute to economic growth, grow more productive and resilient agricultural plots, and have better nourished families. They are more effective environmental stewards and have greater ability to cope with shocks from natural disasters such as drought. In locations impacted by conflict, including local women in peacebuilding processes increases the probability that conflict will end within a year by 24% (Stone, 2014). Additionally, ensuring female participation and leadership in implementing peace plans significantly increases the likelihood of lasting peace. The dual role of educating women and girls in climate change mitigation and peacebuilding work makes their inclusion in environmental peacebuilding strategies essential.

It is my hope that this study has contributed to understanding the mechanisms linking climate change induced drought, migration, sociopolitical instability and conflict at the subnational level. Better understanding these links between climate impacts and conflict will enable more precise targeting of locations for urgently needed environmental peacebuilding interventions. While this study was bound by a number of limitations, it lays out a potential framework to guide future research that may enable high impact environmental peacebuilding work. Conducting follow-up research and corresponding

conflict-prevention work is urgent and calls for immediate funding and support at the national level. While the potential for climate change to induce international crises in the coming few years is tremendous, so are the potential rewards: Breaking the cycle of climate change and conflict, stabilizing and reversing greenhouse gas emissions, and saving millions of lives before the end of the century. Precisely targeted environmental peacebuilding work that also curbs greenhouse gas emissions is perhaps the most cost-effective intervention for directly saving lives and ensuring global peace and security available today.

Appendix I

List of Acronyms

ADT	U.S. National Guard Agricultural Development Team
AFRICOM	U.S. Africa Command
CAGR	Compound Annual Growth Rate
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CIESIN	Center for International Earth Science Information Network
GAR	Global Assessment Report on Disaster Risk Reduction
GIS	Geographic Information Systems
GPW	Gridded Population of the World
IFPRI	International Food Policy Research Institute.
IIASA	International Institute for Applied Systems Analysis
IPCC	Intergovernmental Panel on Climate Change
ISIS	Islamic State of Iraq and Syria
LCCSY	Local Coordination Committees of Syria
MENA	Middle East and North Africa
NDVI	Normalized Difference Vegetation Index
SARG	Syrian Arab Republic Government
UN	United Nations
UNCS	UN Cartographic Section
UNDP	UN Development Program

UNEP   UN Environment Program

UNFAO   Food and Agriculture Organization of the United Nations

Appendix II

Works Consulted Regarding Protest Occurrence by Subdistrict

This list has been compiled separately from other bibliographical sources for use by others who may wish to replicate or build on the data sources and methods used in this study.

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Appendix III

R Code Used in Variable Construction and Analysis

Relevant R code files and datasets used in this study are available for download at https://drive.google.com/drive/folders/0B-Dh8O56oYVkSVBzc2NoTDZxNkE?usp=sharing. For ease of reference, portions of code referred to in earlier chapters are also provided here.

Variable Construction

Raw data used, as well as data for outcome variables generated using the below code, are available in data_by_nahia.csv, provided via the above shared folder. The geosphere package is required to run portions of the code below.

Population Variables

```
## CAGR 1990-2000:
data$popgrowth_1990_2000 <- data$total_pop_00-data$total_pop_90
data$cagr_1990_2000 <- (data$popgrowth_1990_2000^(1/10))-1


## 2006:
sum(data$total_pop_06, na.rm=TRUE)
## [1] 41,143,980
## The world bank estimated total is 18.8 million, so we'll scale
to match.
sum(data$total_pop_06, na.rm=TRUE)*18800000/41143980
## [1] 18800000
data$total_pop_06_adj <- data$total_pop_06*18800000/41143980
```

```
data$pdens_06 <- data$total_pop_06_adj/data$area_sqkm

data$log_pdens_06 <- log(data$pdens_06)



## 2008:

sum(data$total_pop_08, na.rm=TRUE)

## [1] 20400883

## The world bank estimated total is 20.35 million, so we'll

scale to match.

sum(data$total_pop_08, na.rm=TRUE)*20350000/20400883

## [1] 20350000

data$total_pop_08_adj <- data$total_pop_08*20350000/20400883

data$popgrowth_2006_2008 <-

data$total_pop_08_adj/data$total_pop_06_adj

data$cagr_2006_2008 <- (data$popgrowth_2006_2008^(1/2))-1



## 2010:

sum(data$total_pop_10, na.rm=TRUE)

## [1] 44497329

## The world bank estimated total is 21.53 million, so we'll

scale to match.

sum(data$total_pop_10, na.rm=TRUE)*21530000/44497329

## [1] 21530000

data$total_pop_10_adj <- data$total_pop_10*21530000/44497329

data$pdens_10 <- data$total_pop_10_adj/data$area_sqkm

data$log_pdens_10 <- log(data$pdens_10)
```

Distances and Closeness

```
latitudes <- c(data$latitude)
```

```
longitudes <- c(data$longitude)

distances <- data.frame(latitudes,longitudes)

for (i in c(1:272)) for (j in c(1:272)){distances[i,(j+2)] <-

distm(c(distances$latitude[j], distances$longitude[j]),

c(distances$latitude[i], distances$longitude[i]))}


distances[distances == 0] <- NA ## Replaces all zero values with

NAs so we don't get infinities. << Line 562 >>

inv_dist <- 1/distances ## Creates an inverse distance matrix

data$inv_dist <- inv_dist ## Adds it to the data frame


data$pop_proportion_06 <-

data$total_pop_06_adj/sum(data$total_pop_06_adj, na.rm=TRUE)


some_vector_06 <- rep(0,272) ## << Line 1005 >>

inv_distances_06 <- rep(0,272)

for (j in c(1:272)){ ## This runs the for loop generating a

vector that contains the population weighted distance of each

nahia from all the other nahias.

 for (i in c(1:272)){some_vector_06[i] <-

inv_dist[j,i+2]*data$pop_proportion_06[i]}

 some_value_06 <- sum(some_vector_06, na.rm=TRUE)

 inv_distances_06[j] <- some_value_06

}

data$closeness_06 <- inv_distances_06 ## This appends the vector

of weighted population closeness to the original dataset as a

column.
```

Agricultural Proximity

```
some_vector <- rep(0,272)

inv_distances <- rep(0,272)

for (j in c(1:272)){ ## This runs the for loop generating a

vector that contains the agriculturally weighted distance of each

nahia from all the other nahias.

 for (i in c(1:272)){some_vector[i] <-

inv_dist[j,i+2]*data$pct_ag_land[i]}

 some_value <- sum(some_vector, na.rm=TRUE)

 inv_distances[j] <- some_value

}

data$ag_prox <- inv_distances ## This appends the vector of

weighted agricultural closeness to the original dataset as a

column.
```

NDVI and Rainfall

```
data$predrought_ndvi_avg <-

(data$ndvi_2000_04+data$ndvi_2001_04+data$ndvi_2002_04+data$ndvi_

2003_04+ data$ndvi_2004_04+data$ndvi_2005_04)/6


data$avg_predrought_rainfall <- (data$rainfall_1981 +

data$rainfall_1982 + data$rainfall_1983 + data$rainfall_1984 +

data$rainfall_1985 + data$rainfall_1986 + data$rainfall_1987 +

data$rainfall_1988 + data$rainfall_1989 + data$rainfall_1989 +

data$rainfall_1990 + data$rainfall_1991 + data$rainfall_1992 +

data$rainfall_1993 + data$rainfall_1994 + data$rainfall_1995 +

data$rainfall_1996 + data$rainfall_1997 + data$rainfall_1998 +

data$rainfall_1999)/20
```

```
data$rainfall_diff_06 <- data$rainfall_2006-

data$avg_predrought_rainfall
```

Cluster Analysis

Cluster analysis was conducted using the below code, which pulls from the

dataset data_by_nahia.csv. The full R file, Cluster Analysis.R, is available for download

via the shared folder linked above.

```
cluster_frame_06 <- as.data.frame(cbind(data$predrought_ndvi_avg,

data$pct_ag_land, data$ag_prox, data$closeness_06,

data$log_pdens_06))

colnames(cluster_frame_06) <- c("predrought_ndvi_avg",

"pct_ag_land", "ag_prox", "closeness_06", "log_pdens_06")


## K-Means Cluster Analysis

set.seed=123456

fit <- kmeans(cluster_frame_06, 3) # 3 cluster solution

## get cluster means

aggregate(cluster_frame_06,by=list(fit$cluster),FUN=mean)

## append cluster assignment

clusters_06 <- data.frame(cluster_frame_06, fit$cluster)
```

Regression Analysis

Regression analysis was conducted using the below code, which pulls from the

dataset lnd_data.csv. The data set and full R file, Regression and Mediation Analyses.R,

are available for download via the shared folder linked above.

Linear Regression Model

```
## Run the regression on all the data.

growth_06_08_all <- lm(cagr_2006_2008 ~ log_pdens_06 +

closeness_06 + rainfall_diff_06 + historical_drought +

pct_ag_land + ag_prox + cagr_1990_2000 +

historical_drought*ag_prox, data=lnd_data)

summary(growth_06_08_all)


## Select cluster 1

lnd_data_c1 <- lnd_data[which(lnd_data$cluster_06==1),]


## Run the regression on cluster 1.

growth_06_08_c1 <- lm(cagr_2006_2008 ~ log_pdens_06 +

closeness_06 + rainfall_diff_06 + historical_drought +

pct_ag_land + ag_prox + cagr_1990_2000 +

historical_drought*ag_prox, data=lnd_data_c1)

summary(growth_06_08_c1)


## Select cluster 2

lnd_data_c2 <- lnd_data[which(lnd_data$cluster_06==2),]


## Run the regression on cluster 2.

growth_06_08_c2 <- lm(cagr_2006_2008 ~ log_pdens_06 +

closeness_06 + rainfall_diff_06 + historical_drought +

pct_ag_land + ag_prox + cagr_1990_2000 +

historical_drought*ag_prox, data=lnd_data_c2)

summary(growth_06_08_c2)
```

```
## Select cluster 3

lnd_data_c3 <- lnd_data[which(lnd_data$cluster_06==3),]


## Run the regression on cluster 3.

growth_06_08_c3 <- lm(cagr_2006_2008 ~ log_pdens_06 +

closeness_06 + rainfall_diff_06 + historical_drought +

pct_ag_land + ag_prox + cagr_1990_2000 +

historical_drought*ag_prox, data=lnd_data_c3)

summary(growth_06_08_c3)
```

Probit Model

```
## Run the probit regression on cluster 1.

protest_probit_c1 <- glm(protest_sum_1_logit ~ cagr_2006_2008 +

rainfall_diff_06 + historical_drought + log_total_pop_10,

family=binomial(link="probit"), data=lnd_data_c1)

summary(protest_probit_c1)


## Run the probit regression on cluster 2.

protest_probit_c2 <- glm(protest_sum_1_logit ~ cagr_2006_2008 +

rainfall_diff_06 + historical_drought + log_total_pop_10,

family=binomial(link="probit"), data=lnd_data_c2)

summary(protest_probit_c2)


## Run the probit regression on cluster 3.
```

```
protest_probit_c3 <- glm(protest_sum_1_logit ~ cagr_2006_2008 +

rainfall_diff_06 + historical_drought + log_total_pop_10,

family=binomial(link="probit"), data=lnd_data_c3)

summary(protest_probit_c3)


## Run the probit regression on all subdistricts.

protest_probit_all <- glm(protest_sum_1_logit ~ cagr_2006_2008 +

rainfall_diff_06 + historical_drought + log_total_pop_10,

family=binomial(link="probit"), data=lnd_data)

summary(protest_probit_all)
```

Mediation and Sensitivity Analyses

Mediation and sensitivity analyses were conducted using the below code, which

pulls from the dataset lnd_data._c1_mediate.csv. The dataset and full R file, Regression

and Mediation Analyses.R, are available for download via the shared folder linked above.

Note that the below code requires the mediation package to run.

Mediation

```
sd(lnd_data_c1_mediate$rainfall_diff_06)

## 57.09888


## One standard deviation below the pre-drought average would be

-57.1. I'll test it with that value.

## Mediation 1: Protest

model.m1 <- lm(cagr_2006_2008 ~ log_pdens_06 + closeness_06 +

rainfall_diff_06 + historical_drought+pct_ag_land + ag_prox +
```

```
cagr_1990_2000 + historical_drought*ag_prox,

data=lnd_data_c1_mediate)

summary(model.m1)


model.y1 <- glm(protest_sum_1_logit ~ log_total_pop_10 +

cagr_2006_2008 + historical_drought + rainfall_diff_06,

family=binomial(link="probit"), data=lnd_data_c1_mediate)

summary(model.y1)


out.1_moderate <- mediate(model.m1, model.y1, sims=1000,

boot=TRUE, treat="rainfall_diff_06", mediator="cagr_2006_2008",

control.value = -57.1, treat.value = 0, dropobs = TRUE)

warnings(out.1_moderate)

summary(out.1_moderate)


## Mediation 2: Casualties

model.md <- glm(protest_sum_1_logit ~ log_total_pop_10 +

cagr_2006_2008 + historical_drought + rainfall_diff_06,

family=binomial(link="probit"), data=lnd_data_c1_mediate)

summary(model.md)


model.yd <- lm(deaths ~ protest_sum_1_logit + log_total_pop_10 +

rainfall_diff_06, data=lnd_data_c1_mediate)

summary(model.yd)


out.d <- mediate(model.md, model.yd, sims=1000, boot=TRUE,

treat="rainfall_diff_06", control.value = -57.1, treat.value = 0,

mediator="protest_sum_1_logit", dropobs=TRUE)
```

```
warnings(out.d)

summary(out.d)


out.d2 <- mediate(model.md, model.yd, sims=1000, boot=TRUE,

treat="rainfall_diff_06", control.value = -114, treat.value = 0,

mediator="protest_sum_1_logit", dropobs=TRUE)

warnings(out.d2)

summary(out.d2)
```

Sensitivity Analyses

```
sens.1 <- medsens(out.1_moderate, rho.by=0.05, sims=1000)

summary(sens.1)


sens.d <- medsens(out.d, rho.by=0.05, sims=1000)

summary(sens.d)


sens.d2 <- medsens(out.d2, rho.by=0.05, sims=1000)

summary(sens.d2)
```

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