

CCAPS  CLIMATE CHANGE
AND AFRICAN
POLITICAL STABILITY



VULNERABILITY TO CLIMATE CHANGE:

Assessing Climate Vulnerability in North Africa

STUDENT WORKING PAPER NO. 3

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ABOUT THE CCAPS PROGRAM

This paper is produced as part of the Strauss Center's program on Climate Change and African Political Stability (CCAPS). The program conducts research in three core areas, seeking to investigate where and how climate change poses threats to stability in Africa, identify strategies to support accountable and effective governance in Africa, and evaluate the effectiveness of international aid to help African societies adapt to climate change. The CCAPS program is a collaborative research program among the University of Texas at Austin, the College of William and Mary, Trinity College Dublin, and the University of North Texas.

The CCAPS program is funded by the U.S. Department of Defense's Minerva Initiative, a university-based, social science research program focused on areas of strategic importance to national security policy. Through quantitative analysis, GIS mapping, case studies, and field interviews, the program seeks to produce research that provides practical guidance for policy makers and enriches the body of scholarly literature in this field. The CCAPS team seeks to engage Africa policy communities in the United States, Africa, and elsewhere as a critical part of its research.

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EXECUTIVE SUMMARY

2011 was a transformative year for North Africa, upending many assumptions about the region's political stability. Regimes that had been ruled by authoritarian governments for decades suddenly erupted in mass protest, leading to the departure of two aging dictators—in Tunisia and Egypt – and on-going civil war in another—Libya. Sudan, for its part, was poised to break apart after the south voted to secede.¹

Amidst all the other challenges faced by the ten countries of North Africa is the issue of climate change. A chronically water scarce region, North Africa possesses some of the richest countries on the continent including Tunisia, as well as a number of its poorest, least well-governed countries like Niger and Chad. If instability persists for North African countries along the Mediterranean, countries like Tunisia and Egypt that have more capacity to address climate change will have to divert their attention from long-run preparedness. These concerns notwithstanding, the results of this study suggest that Sudan and the Sahelian countries are the most vulnerable in the region to climate change given the confluence of physical exposure, population, household level vulnerability, and governance.

Due to poor governance, inadequate infrastructure, and a wide variety of alternate threats, many North African countries are currently unable to effectively respond to climate-related hazards or develop and execute strategies to minimize the long-term effects of climate change. Mali, Niger, Chad, and Sudan, along the southern edge of the Sahara Desert, are particularly vulnerable. Destructive weather events may exacerbate the volatile political conditions in these countries, affecting the ability of national governments to respond to climate change.

This study aims to augment the recent research conducted by the Strauss Center's program on Climate Change and African Political Stability (CCAPS) at the University of Texas at Austin. The CCAPS program developed a model to assess vulnerability to climate change throughout Africa at the sub-national level. The model included data on quality of governance, public access to health care and education, general health measures, population, recent political atrocities, and destructive weather events.

In order to refine this model to account for region-specific characteristics, this study adds three factors specifically relevant to North Africa: migration, water resources, and terrorism. Outgoing migration often harms a country's adaptive capacity through "brain drain," as motivated individuals leave the country to pursue better economic opportunities elsewhere. Incoming migration can potentially exacerbate pre-existing ethnic strife and increase competition for scarce job opportunities. If a country suffers from high levels of poverty, it is unlikely to incorporate incoming migrants into society in a constructive way. Water is a crucial but scarce resource throughout the region. Most of the countries are highly dependent on agriculture as a source of income, leaving them vulnerable to erratic rainfall patterns. Additionally, international competition for water resources might potentially spark conflict between states, particularly in the case of Egypt, Sudan, and their respective dependence on the Nile River for irrigation. Terrorism presents an immediate threat to a government's rule, causing it to allocate resources to combat the threat. This may distract state leaders' attention from long-term threats such as climate change.

Mali, Niger, Chad, and Sudan all appear extremely vulnerable to destructive weather events due to their high exposure to such physical threats, poor governance, and extremely poor access to health and education. Sudan appears to be the most vulnerable country in the region.²

The countries along the Atlantic and Mediterranean coasts appear to be less vulnerable than their southern neighbors. Interestingly, Libya appears to be largely insulated from climate threats according to the model. Its small population, its previously stable (albeit repressive) regime, high

level of education and health care access, and sustainable access to water resources all appear to enable Libya to address the specific climate threats that it faces. Algeria exhibits the highest vulnerability of the coastal states, as it experiences the same damaging climate threats as Morocco and Tunisia (particularly droughts), but does not have the necessary governance to address these problems. Additionally, Algeria faces the most acute terrorist threat of any country in North Africa. This may force the government in Algiers to allocate more resources to combat terrorism at the expense of developing long-term strategies to mitigate and adapt to future effects of climate change.

INTRODUCTION

2011 was a transformative year for North Africa, upending many assumptions about the region's political stability. Regimes that had been ruled by authoritarian governments for decades suddenly erupted in mass protest, leading to the departure of two aging dictators in Tunisia and Egypt, as well as ongoing civil war in Libya. Sudan, for its part, was poised to break apart as the south voted to secede.

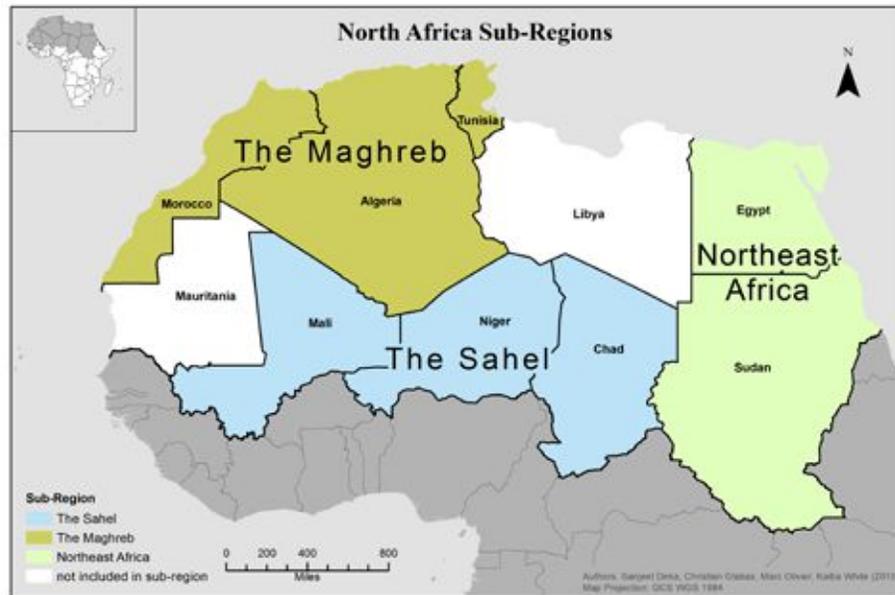
Amidst all the other challenges faced by the ten countries of North Africa is the issue of climate change.³ A chronically water scarce region, North Africa possesses some of the richest countries on the continent like Tunisia, but also a number of its poorest, least well-governed countries like Niger and Chad (see Figures 1 and 2, and see Appendix A for data sources for maps throughout this paper).

Figure 1



This regional study focuses on ten countries in the North Africa region, with Sudan represented as a single country prior to South Sudan's secession in July 2011.

Figure 2



This study divides analysis of North African into three sub-regions: the Sahel, the Maghreb, and Northeast Africa.

Some commentators have invoked climate change and the effects of distant weather shocks on food prices as one of the principal reasons that sparked protests in the region in spring of 2011.⁴ While provocative, trying to identify the relative importance of climate shocks for recent events is likely to be contentious. The protests and instability have many causes, and there are a myriad of reasons, including climate shocks but also diversion of corn for ethanol, that account for food price increases from 2010 to 2011 that were the source of grievances stated in the protests.

A full assessment of the implications of the unfolding political tumult in the region and its relationship to climate change is beyond the scope of this paper. However, it is clear that if instability persists for North African countries along the Mediterranean, countries like Tunisia and Egypt with more capacity to address climate change would have to divert their attention from long-run preparedness. These concerns notwithstanding, the results of this study suggest that Sudan and the Sahelian countries are the most vulnerable in the region to climate change given the confluence of physical exposure, population, household level vulnerability, and governance.

The regional findings from North Africa can be put in perspective. Africa is widely considered to be highly susceptible to the negative consequences of climate change. In the literature on climate change and security, many observers suggest possible links between past climate-related disasters and violent conflict. In June 2007, United Nations Secretary General Ban-Ki Moon published an op-ed in the *New York Times*, pointedly asserting that the conflict in Darfur had begun as "an ecological crisis, arising at least in part from climate change."⁵ As claims of causal linkage between climate change and security grow louder, researchers are trying to identify the potential effects of climate change in order to understand when and where climate-induced conflicts and other security outcomes may occur.

Climate models of the likely future consequences of climate change on the African continent exhibit a high degree of uncertainty.⁶ While climate models show general agreement with respect to temperature trends, global climate models have widely different projections for precipitation for much of the continent, making it very difficult to anticipate the future impacts of climate change.

A new approach has emerged in the debate on climate-related effects that foregoes such ambitious estimates of what will happen in the future, focusing instead on knowledge of current and past factors to identify which regions will likely be most vulnerable to destructive climate events. “Vulnerability mapping” incorporates data on a wide range of factors in order to identify areas where weaknesses in multiple factors converge, rendering an area particularly vulnerable to potential threats. Although the research team was interested specifically in vulnerability to climate events—and included data on such incidents accordingly—many other factors affect regional vulnerability. Factors such as poverty, health, and governance all affect a country’s ability to react to crises, as well as plan for the future. These factors can be measured and overlapped graphically, constructing a comprehensive image of a state’s “adaptive capacity” that can be communicated in visual form.

A preliminary study published by the Climate Change and African Political Stability (CCAPS) program examines the entire African continent for vulnerability to climate events.⁷ This paper continues the effort, narrowing the focus of the study to North Africa. While including all of the variables employed in the CCAPS study in the calculations of vulnerability,⁸ the paper also incorporates three variables believed to be directly relevant for North Africa. These variables are water availability, migration, and terrorism—issues that frequently come up in policy-related discussions about the region.

Water scarcity is particularly relevant to the region due to the high dependence of regional economies on agriculture. The impacts of water scarcity on livelihoods can generate internal social conflict as different groups compete for allocation of and access to water. Internationally, though states have often avoided armed conflict over water resources, it is possible to observe conflictual dynamics between countries in a warming world of increased water scarcity and rising demand for water.

Migration is harming many North African countries’ relations with Europe as well as threatening to overwhelm their ability to provide basic services to their populations. While there are many reasons why people may be induced to migrate, climate change—primarily through its effect on livelihoods—may constitute another reason why North Africans seek better opportunities outside of the region. In addition, North Africa itself is a transit hub for migrants from the rest of the continent.

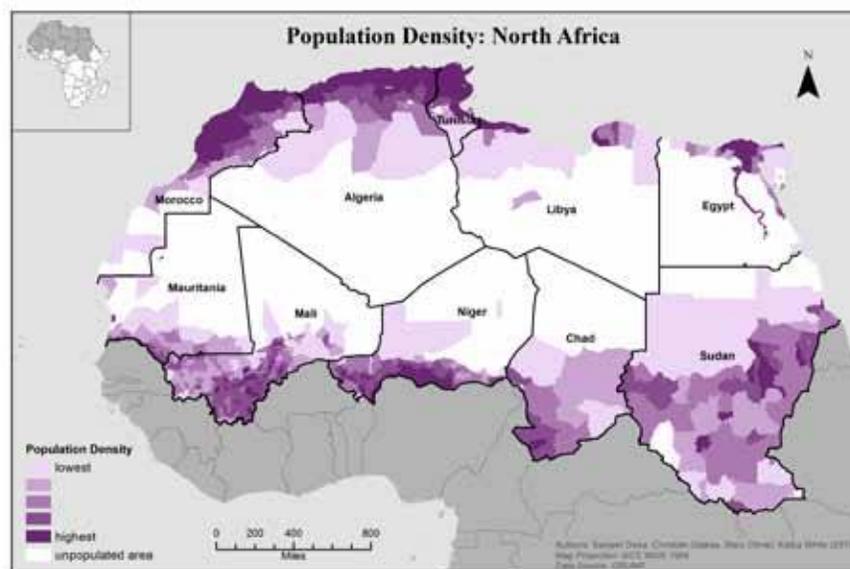
Terrorism represents a short-term threat to those governments’ very survival, and state leaders often face the need to prioritize short-term threats over long-term threats. An imminent threat such as terrorism requires the state to allocate valuable time, energy, and resources to address that threat, at the expense of other potential vulnerabilities like climate change. States beset by both terrorism and the effects of climate change will face difficult trade-offs that may inevitably favor short-term priorities.

This paper is divided into three sections. The first section offers a brief analysis of developing trends in North Africa, particularly in relation to key variables such as climate, migration, and terrorism. The second section offers a comprehensive review of the data sources and an explanation of the methodology. The third section presents the findings of the analysis and policy implications.

PART 1: THE NORTH AFRICAN NARRATIVE

The population of the North African region is most concentrated along the coastal regions of Morocco, Algeria, Tunisia, Libya, and Egypt (see Figure 3). Egypt is the region's most populous country, home to over 80 million residents as of 2008 (see Table 1).⁹ The countries of the Maghreb had a collective population of roughly 65 million in 2000, a number projected to increase to over 72 million by 2010.¹⁰ The region has experienced significant urbanization in recent years. In 1970, 60 percent of the region's population lived in the countryside. Today, 60 percent of the population lives in cities.¹¹ Ballooning urban populations have placed a great deal of stress on the governments' abilities to provide basic services. Many cities in the region are unable to expand infrastructure to adequately meet the challenges of such rapid urbanization, and they struggle to provide sufficient drinking water, maintain functioning sewer systems, collect urban waste, and regulate air quality.

Figure 3



The population of North Africa is heavily concentrated along the coasts of Morocco, Algeria, Tunisia, Libya, and Egypt.

Table 1. Population of Countries in North Africa

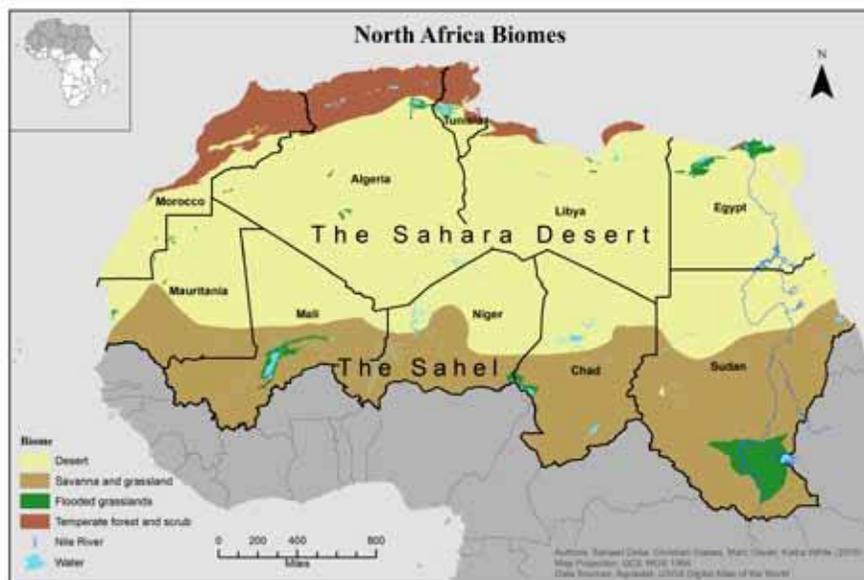
Country	Population (in millions)
Egypt	80.3
Sudan	39.2
Morocco	33.7
Algeria	33.3
Niger	13.9
Mali	13.5
Tunisia	10.1
Chad	10.1
Libya	6.0
Mauritania	3.1

Source: CIA World Fact Book, 2008

Climate and Water

North Africa does not significantly contribute to overall greenhouse gas emissions, yet climate change will heavily affect the region. With about 1,200 cubic meters of water per person per year, North Africa is one of the driest regions in the world compared with a global average of around 7,000 cubic meters.¹² Much of North Africa's climate is arid to semi-arid, but there are several climates within the region: a Saharan climate in the south, an oceanic climate in the west, and a Mediterranean climate in the north (see Figure 4).¹³ The more fertile and watered zones are found in the north, sometimes with small forests.

Figure 4



North Africa has several different climates: a Saharan climate in the south, an oceanic climate in the west, and a Mediterranean climate in the north.

Every day life in the region is closely linked to the climate and fluctuations in rainfall.¹⁴ The economies of many North African countries are highly dependent on water, tourism, coastal zones, and agriculture, which accounts for 85 percent of the region's water usage.¹⁵ Agriculture is primarily rain-based, except in Egypt, which extensively employs irrigation. Desertification is of particular concern along the southern fringes of the Sahara in the Sahel region, which stretches from Mauritania in the West through Mali, Niger, Chad, and Sudan in the East. A shortage of water in many of these areas has led to increased water demand for irrigation and decreased agricultural production.

Natural resources are fragile and vulnerable in North Africa. Most water systems are reliant on surface water, which impacts the water quality. While all of the North African countries face acute water shortages, Morocco, Algeria, and Tunisia—collectively known as “the Maghreb”¹⁶—are particularly water-stressed, receiving less than 1,000 cubic meters of water per inhabitant per year.¹⁷ Another concern is that rainfall is predicted to decrease in frequency but increase in intensity. Rapid and violent water flows can transport 500 to 2,000 metric tons of sediment per square kilometer each year, which threatens the viability of agricultural lands.¹⁸ Overdrawing groundwater supplies also allows infiltration of saltwater, particularly in coastal regions. Increased salinization degrades soil quality and reduces agricultural productivity. Rapid population growth in urban areas and the countries of the Sahel region places greater stress on local natural resources and increases their vulnerability to future climate change. In addition to increased competition for diminishing freshwater supplies, removal of limited forest cover presents another threat to scarce resources.

The historical competition between Egypt and Sudan over the Nile deserves particular attention in the region. Because of Egypt's huge population and high degree of dependence on the Nile for irrigation, Cairo can be expected to react forcefully to any disruption, by Sudan or other states, to the status quo regarding upstream usage of water. While academic literature on water scarcity suggests that states have mainly dealt with inter-state disputes over water relatively pacifically,¹⁹ climate change may make it harder for states to handle dwindling water resources as effectively. Thus, one potential security concern associated with climate change in the future is inter-state conflict over water scarcity, particularly in the event of abrupt shocks and anomalies in available water resources. Ten countries share the waters of the Nile. In 2010, five of them—Ethiopia, Uganda, Tanzania, Rwanda, and Kenya—signed an agreement to share water, which would dramatically affect Egypt's downstream water rights. Egypt and Sudan refused, as both possess the right—dating back to a 1929 agreement—to veto upstream dams.²⁰ The Democratic Republic of the Congo sided with Egypt and remains outside the agreement, while Burundi signed the agreement in March 2011.²¹ Ethiopia appears poised to move forward on dam construction regardless.²² With some states in the region, including Ethiopia, leasing lands to foreigners to grow crops, such tensions could take on new disturbing transnational implications.²³

Another potential causal pathway may lead to intra-state conflict over water. Even though quantitative academic literature has found only mixed evidence of a causal relationship between drought and conflict, anecdotal evidence has suggested that conflicts within states involving scarce water can become violent.²⁴ While a causal relationship between water stress and conflict has not been established, water scarcity, particularly in this region, is another stressor that can create tensions between groups both within and between countries.

Migration

Migration from and through North Africa to Europe causes stress between governments on both sides of the Mediterranean Sea. The European Union (EU) has pressured North African countries to adopt more restrictive immigration laws and to increase border controls.²⁵ On a more cooperative note, the EU has also signed a free trade agreement with many North African states

to increase development in North Africa and reduce the relative appeal of European countries to potential African migrants.²⁶ Many European states have negotiated bi-lateral Temporary Migration Programs (TMPs) with North African countries to alleviate population pressures and connect African labor supply with the European demand. In addition to the direct benefits enjoyed by the migrants and the companies that employ them, the migrants' remittances sent back home provide substantial benefits to their home countries. In 2004, remittances in Morocco constituted 8.4 percent of the total GDP.²⁷

Migration from North African states is not a new issue, as it has been part of the states' national development strategies for many decades. Post-colonial migration was relatively low compared to the rates seen today. Migration from Algeria to France fell during the Algerian war for independence. With French labor demand thus unfulfilled, migration from Morocco to France subsequently increased to fill the gap. During the late 1960s and 1970s, migration from North Africa to Europe increased. Tunisia and Morocco implemented pro-emigration policies, hoping to take advantage of the return of educated and wealthy citizens from developed nations.²⁸ In Egypt, on the other hand, President Gamal Abdel Nasser discouraged labor emigration in the 1950s and 1960s by requiring exit visas in an effort to prevent "brain drain."²⁹

The recession that resulted from the 1973 oil crisis marked a pronounced shift in the patterns of Afro-European migration. European demand for skilled labor dropped as skyrocketing oil prices caused prices of other goods to increase proportionally. Many European countries enacted restrictive immigration policies in order to stem the continuing flow of migrants looking for work.³⁰ Concomitantly, demand for labor increased in the Arabian Peninsula where huge oil profits provided funds for ambitious national development programs in oil-producing Arab states. While the Gulf region boomed, Anwar Sadat's *infitah* (economic opening) increased demand for labor in Egypt as well, and Egypt's recognition of Israel in 1978 opened the door to billions in U.S. development dollars.

Political upheaval in the late 1980s and early 1990s reversed the longstanding trend of emigration from Egypt, Libya, and the Maghreb to the Gulf countries. The UN embargo on Libya and the 1991 Gulf War greatly diminished the appeal of these countries as migration destinations. The outbreak of civil war in Algeria in 1992 led to a flood of refugees and migrants looking to the North. These conflicts renewed migrant interest in Europe. North Africa resumed its role as an origin and transit zone for migrants going to Europe, and assumed the new role of unintended destination for many who did not succeed in reaching Europe.³¹

Two distinct migration patterns exist in North Africa today. Morocco, Algeria, and Tunisia are integrated in the Euro-Mediterranean migration system, while Egypt remains largely connected with migrant movement between Africa and the Arabian Peninsula. However, in the last decade, migration from Egypt to Europe has increased. Libya is a center of intra-regional migration due to its high demand for unskilled labor and limited enforcement of migration laws. In Europe, the combination of low fertility rates, a long Mediterranean coastline, and established migrant networks will continue to draw immigrants from North Africa.

To what extent is climate change driving migration patterns? Precise attribution of such causal links is beyond the scope of this study. However, climate change will likely contribute another "push" factor that induces people from the region and wider continent to move. Swift-onset extreme weather events could induce refugees to flee the destruction of floods. Over the longer term, agriculturalists and traditional pastoralists could leave land ruined by desertification or salinization of groundwater for urban areas or other countries. North Africa is both a source of potential migrants and a destination. Given large concerns about their ability to assimilate migrants from North Africa, European countries were already concerned about migration from the region before the wave of political instability in 2011 induced thousands to flee. While recent events are of more immediate concern, climate change, particularly through its effect on livelihoods, may be among

the many reasons North Africans move, though the main destinations may be other countries in the region or in the Arabian Peninsula rather than Europe.

Given the region's greater standing of living and its location near Europe and the Arabian Peninsula, North Africa attracts migrants from the rest of the continent. Both rural to urban migration and intra-regional migration could exacerbate tensions between migrants and local populations.

This study considers migration as two separate phenomena with potentially different effects on vulnerability: out-migration and in-migration. Regarding out-migration, potential endogeneity exists between out-migration and vulnerability. That is, large numbers of people leaving a specific country may reflect that country's vulnerability as much as contribute to it. However, in the view of this study's research team, out-migration has a linear and positive (i.e. harmful) impact on a country's vulnerability due to the potential reduction in the labor force, especially the flight of skilled professionals.

Regarding in-migration, the familiar North African narrative assumes that migration from Sub-Saharan Africa has a potentially destabilizing effect on the Maghreb. However, the U.S. accepts a much greater number of immigrants than any other nation, and it would be difficult to claim that this increases U.S. vulnerability in any tangible way. Clearly, there are other relevant factors that determine when in-migration may have negative consequences on a country's well being. Extremely high levels of poverty or a large number of recent ethnic wars may render a country unable to incorporate incoming migrants into the social and economic fabric of the nation in a constructive way. Moderate levels of both variables, in combination, could cause incoming migration to have a potentially destabilizing effect.

To operationalize this theory, this study utilized the rankings of all African countries for both poverty and ethnic wars and separated each into quintiles, with "5" representing the highest quintile of poverty or ethnic wars, and "1" representing the lowest quintile of each variable (see Table 2). Each country's quintile value for poverty was then multiplied by its quintile value for recent ethnic wars. If the product of these values is 5 or higher, the country's incoming migration is coded as having a positive (i.e. harmful) impact on its vulnerability. If the product is below 5, incoming migration does not affect a country's vulnerability score.

Table 2. Migration as a Driver of Vulnerability in the North African Countries

North African Countries	Ethnic War Quintile	Poverty Quintile	Ethnic War x Poverty	In-Migration Quintile	Out-Migration Quintile
Libya	1	1	1	5	1
Algeria	1	2	2	2	5
Tunisia	1	2	2	1	2
Egypt	1	3	3	1	5
Morocco	1	3	3	1	6
Mauritania	1	4	4	2	1
Niger	1	5	5	3	2
Chad	2	5	10	1	1
Mali	2	5	10	1	4
Sudan	5	4	20	6	2

Note: A gray digit indicates a country whose value for "Ethnic War x Poverty" is less than 5, and is not considered as contributing to the country's vulnerability.

Terrorism

Causal links between climate change and terrorism have not been established. However, terrorism presents an immediate threat to state stability that governments must address. This may cause the state to divert resources away from the development of adaptation strategies addressing the effects of climate change in order to address the terrorist threat.

The primary terrorist movements found in North Africa bear some resemblance to general movements of Islamic terrorism. In Egypt, the efforts of both the Muslim Brotherhood and Jammāt Islamiya historically focused on opposing the influence of Western secularism in the Egyptian government, as well as the authoritarian nature of ex-President Mubarak’s regime. In Algeria, Al Qaeda in the Land of the Islamic Maghreb (AQIM)’s 2006 adoption of the “Al Qaeda” moniker illustrates their shared ideology with the core Al Qaeda movement. However, the group maintains a regional focus based largely on the lingering conflict that remains after the Algerian civil war of the 1990s. The bulk of the terrorist attacks in the region in the last two decades occurred in Algeria. More recently, an off-shoot of AQIM has conducted a series of attacks and kidnappings across the Sahel affecting Mali and Niger, among other countries. For these countries, climate change and terrorism may constitute twin challenges that will compete for scarce government resources for attention.³²

This study focuses on how terrorism could pose a rival security concern that could divert attention from long-term climate preparedness. For this purpose, terrorist attacks are interpreted as the degree to which certain non-state actors are willing to use violence as a means to engender political change. On the surface, past terrorist attacks from 1995 to 2007 are examined as an indication of where future terrorist incidents may occur. More broadly, regions that experience terrorist attacks can be interpreted as regions where the state is unable to effectively protect its citizens. As mentioned previously, states that suffer from widespread terrorist attacks must devote resources to combat this short-term threat, diverting funds and manpower from more long-term concerns such as climate change. Because the terrorist attacks are geo-coded to latitudinal and longitudinal coordinates for the city in which they occurred, there are a number of locations that experienced multiple attacks. In order to distinguish a city that experienced multiple attacks from a city that only suffered one, cities were classified into quintiles based on the number of attacks that each city experienced. With each quintile represented by its own raster, an aggregate vulnerability raster for terrorism was created by assigning a higher vulnerability score to quintiles with a larger number of attacks (see Table 3).

Table 3. Vulnerability Scores for Cities Based on Number of Terrorist Attacks

Number of Terrorist Attacks	Score Assigned to Each City
1-4	1
5-15	2
16-56	3
57-308	4
309-362	5

PART 2: METHODOLOGY

Building on a previous study by the CCAPS program that assessed vulnerability to climate change across Africa, this study sought to assess adaptive capacity and vulnerability to climate threats on a regional basis. This study thus included all variables employed by the CCAPS study in calculating vulnerability and added the three additional variables discussed above that are believed to be directly relevant to North Africa: water availability, migration, and terrorism. This study then organized these variables into the same four groups or “baskets” as in the CCAPS study: physical vulnerability, population, household and community vulnerability, and governance and political violence.³³ Each basket was given equal weight in the overall vulnerability assessment (see Table 4).

Baskets

Physical Vulnerability

This basket combines all of the climate-related and geographic variables. Specifically, the team considered past data on *cyclone surge frequency*, *cyclone wind frequency*, *flood frequency*, *drought frequency*, and *wildfire frequency*—all occurring between 1980 and 2001, as well as low elevation coastal zones, freshwater availability, and other measures of water vulnerability. This basket aims to provide the best estimate for where future extreme weather events and climate-related hazards may occur, based on historical incidence of these same hazards. This basket also identifies which countries exhibit water-related vulnerability based on the percentage of available water consumed and on the percentage of consumed water that originates from sources outside the country. All weather-related data (Cyclone Surge, Cyclone Wind, Flood Frequency, Fire Frequency and Drought Frequency) come from UNEP/GRID-Europe, water data come from AQUASTAT and the World Bank, and the data on low-elevation coastal zones are taken from the United States Geological Survey. Given the importance of drought and low-elevation coastal zone exposure in this region, both of these indicators are over-weighted at 23.33 percent in this study’s physical vulnerability index. The other remaining indicators on cyclones, wildfires, and floods each receive a weight of 7.5 percent.

Regarding water vulnerability, this study incorporates several water variables into the assessment of a country’s water-related vulnerability. “Percentage of Population with Access to Clean Water” acts as a proxy for the level of development infrastructure and attempts to gauge the region’s resilience to weather-related disasters. “Agricultural Withdrawal” measures the annual quantity of water withdrawn for irrigation and livestock purposes, providing an estimate of current irrigation. The “Dependency Ratio” measures the percent of total renewable water resources originating outside a country’s borders. A high dependency ratio would indicate a high potential vulnerability since the water-origin country may be able to increase its use of water at the downstream country’s expense. “Total Water Withdrawal” and “Total Groundwater Available” estimate how much of a country’s available in-country water resources are withdrawn each year. In sum, the water vulnerability variables measure how much water a country has within its borders, how much of that water is consumed each year, and how much of the total water consumed flows in from beyond the country’s borders. Each of these indicators is given the same weight in the overall water index, which is collectively given a weight of 23.33 percent.

Population and Migration

This basket attempts to gauge how many people are in each country, and how many people enter and exit each country—either in a specific year or over the span of several years. Specifically, this basket examines *population density and migration*. It incorporates data on past ethnic wars and poverty in order to identify areas in which migration may present a risk to stability. Population data come from the Global Rural-Urban Mapping Project (GRUMP) and were collected in 2000. Migration data come from the Global Migrant Origin Database, developed by the Development Research Center on Migration, Globalization, and Poverty. Created in 2000, the matrix was most recently updated in 2007. Net migration numbers are not included; rather, the study includes data on the total number of people leaving each country and the total number of people arriving in that country in a particular year. Poverty data come from the Human Poverty Index 2007 in the United Nations Human Development Report 2009. Ethnic war data come from the Political Instability Task Force (PITF) and span the years 1995 to 2007.

Household Vulnerability

This basket combines the education and health variables. The included variables are *literacy rate, primary school enrollment, adjusted infant mortality, life expectancy, percentage of children under five years of age who are underweight, percentage of the population with access to clean water, per capita spending on health, and nursing and midwife density*. These variables estimate a country's resilience to climate-related hazards. Data for this basket come from the World Bank, the Center of International Earth Science Information Network, and the World Health Organization.

Governance and Political Violence

This basket combines variables that attempt to gauge the effectiveness of each country's government and its susceptibility to sub-national violent conflict. It includes indicators for government effectiveness, voice and accountability, global integration, political stability, volatility in regime, years since major regime change, atrocities committed, and terrorist attacks. Data for *government effectiveness and voice and accountability and political stability* come from the World Bank, *global integration* from the KOF Index of Globalization, *years since major change and volatility of the regime* from Polity IV, *past atrocities* from the Political Instability Task Force, and *past terrorist attacks* from the Global Terrorism Database.

Table 4. Weighting Scheme of Four Baskets and Indicators

Basket	Indicator	Weight within Basket	Data Source
Physical Vulnerability	Cyclone Surge	7.50%	UNEP/GRID-Europe
	Cyclone Wind	7.50%	
	Flood Frequency	7.50%	
	Fire Frequency	7.50%	
	Drought Frequency	23.33%	
	Water Vulnerability*	23.33%	AQUASTAT, World Bank
	Low Elevation Coastal Zones	23.33%	U.S. Geological Survey
Population and Migration	Population Density	50%	GRUMP
	In-Migration	30%	Global Migrant Origin Database
	Out-Migration	20%	
Household Vulnerability	Literacy Rate	14.28%	World Development Indicators
	School Enrollment	14.28%	
	Adjusted Infant Mortality	14.28%	Center for International Earth Science Network
	Life Expectancy	14.28%	
	% of children under 5 underweight	14.28%	World Health Organization
	Per Capita Spending on Health	14.28%	
	Nursing and Midwife Density	14.28%	
Governance and Political Violence	Government Effectiveness	17%	World Bank
	Voice and Accountability	17%	
	Global Integration	17%	KOF Index of Globalization
	Years Since Major Change	8.5%	Polity IV
	Volatility of the Regime	8.5%	
	Past Atrocities	17%	Political Instability Task Force
	Past Terrorist Events	15%	Global Terrorism Database
<p>Note: Variables labeled in red represent the additions to the variables included in Busby et al. * See Physical Vulnerability section in Part 3.</p>			

Sensitivity Analysis

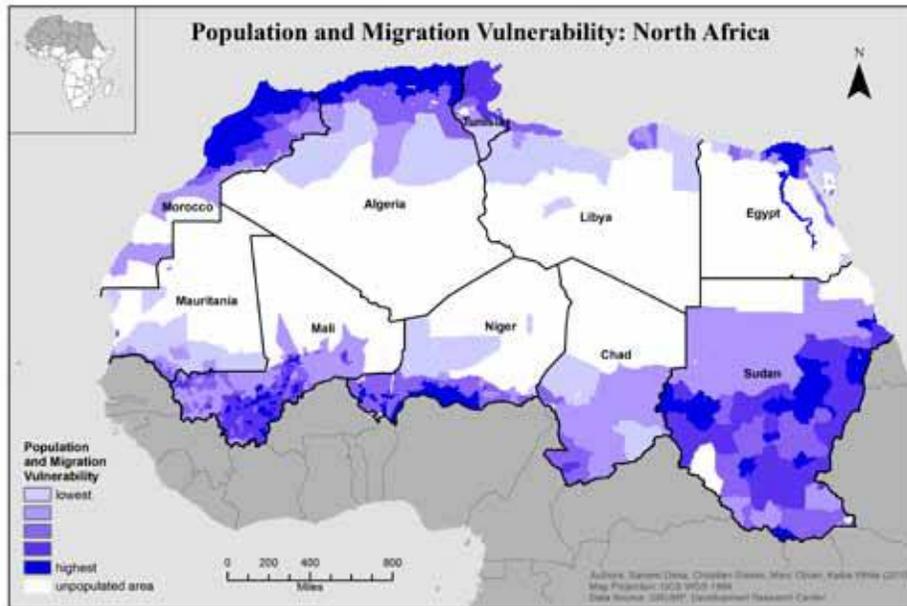
The overall vulnerability map for North Africa reflects the threats to regional stability, as represented by the selected variables (see Figure 9). This map identifies the areas that are most vulnerable to the effects of climate change and that, due to their scores on a wide range of variables, may be unable to meet potential threats.

The study team was interested in the Maghreb due to the region's high incidence of terrorist attacks. Although the team used the terrorism data as a factor that affects vulnerability in the overall vulnerability map, terrorism data was also used as a measure to determine how well the map might mirror vulnerable areas more broadly. To this end, the team created a second vulnerability map, removing the terrorism data, to assess how many attacks fall in the vulnerability quintiles without concern about double-counting the attacks.³⁴

If the variables included in this second vulnerability map affect a region's adaptive capacity, then it would be expected that the terrorist attacks that actually occurred during this time period would lie in the most vulnerable areas. Using tools available in ArcGIS, it is possible to aggregate the number of terrorist attacks that occurred in each vulnerability quintile. Calculating the area of each quintile allows calculation of the average number of attacks per area—1,000 km² in this case.

Although no causal connection has been established between climate events and frequency of terrorist attacks, a similar analysis to the one discussed above was also created, aggregating the number of terrorist attacks by the physical vulnerability basket quintiles. This allowed the team to look for any trends in average number of attacks per 1,000 km² in these weather vulnerability quintiles.

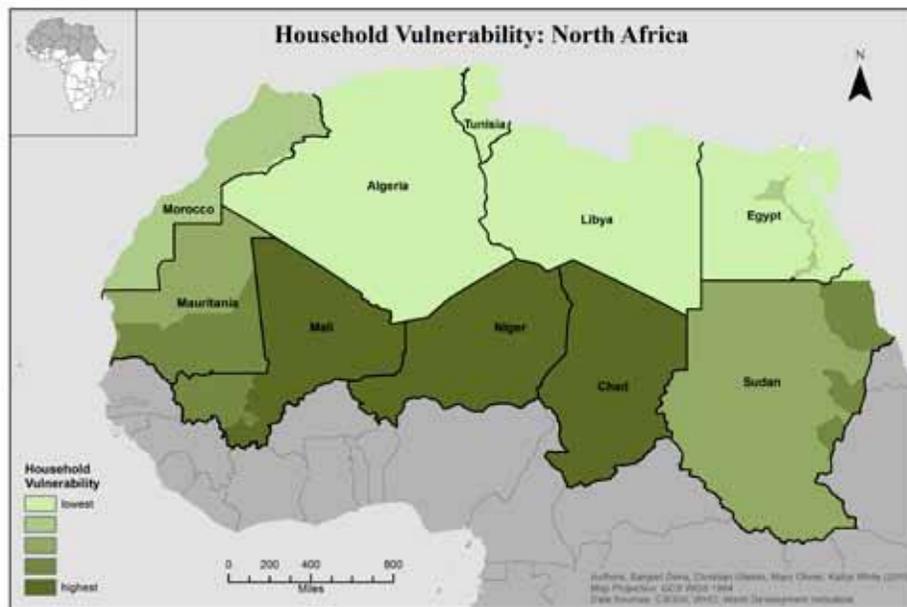
Figure 6



Household Vulnerability

As seen in the household vulnerability map shown in Figure 7, a trend is beginning to emerge in which Mali, Niger, Chad, and Sudan are consistently exhibiting higher vulnerability levels than the Mediterranean countries to the North.

Figure 7



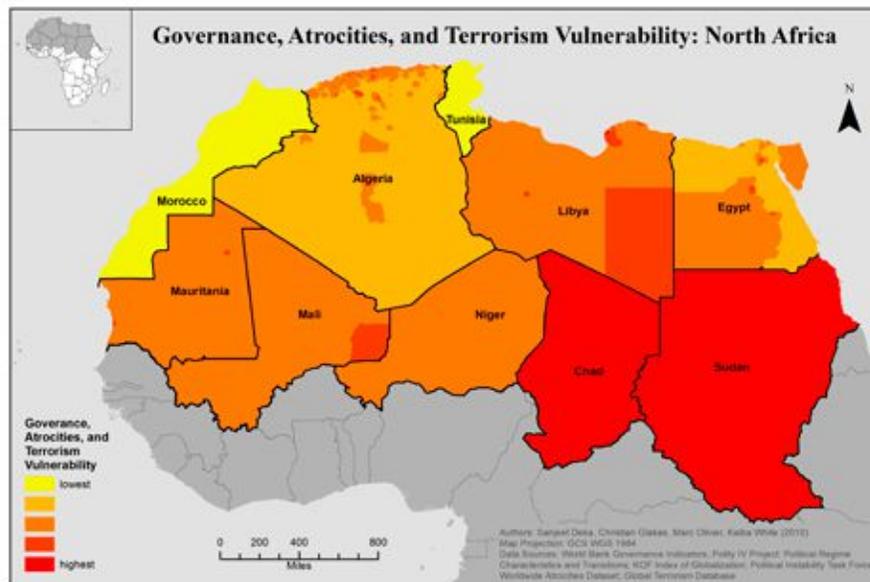
Governance and Political Violence

The governance basket includes variables for quality of governance, incidence of terrorist attacks, and politically motivated atrocities. Governance indicators are national-level data, thus representing the base layer of color. All sub-national variation shown in Figure 8 is attributable to terrorist attacks and politically motivated atrocities. Sudan and the countries of the Sahel appear particularly vulnerable based on poor quality of governance.

The Algerian coast exhibits a high number of terrorist attacks, and some attacks can be seen in Egypt along the course of the Nile. Sudan and Chad appear at first glance to be free of terrorist attacks or atrocities, as they do not exhibit any sub-national variation. However, this is a reflection of deeply inadequate governance, which is so problematic in these two countries that each lands in the highest quintile of vulnerability before terrorism or political violence enters into the equation.

The block-shaped areas of higher vulnerability in Libya and Egypt reflect the large administrative areas in which the political atrocities are reported.³⁷ Libya's high vulnerability scores reflect its poor scores on the governance indicators such as voice and accountability, government effectiveness, and global integration. However, this belies the effective measures that the Libyan government has taken to address the country's water scarcity issues. The Great Man-Made River Project, for example, pipes water from aquifers under the Sahara (within Libya's borders) to the population centers on the coast. The governance rankings of Mediterranean countries—Egypt, Tunisia, and Libya—through the Polity IV indicators reflect the long-running political stability prior to recent political instability and thus appear better than would be suggested by the events of early 2011.

Figure 8

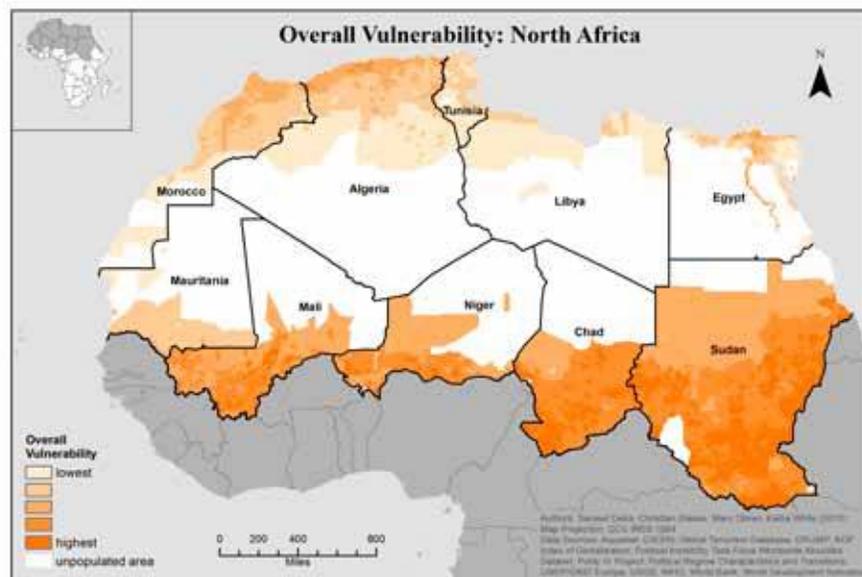


Overall Vulnerability

Figure 9 layers all four baskets of indicators to develop a picture of overall vulnerability of North Africa due to these various sources of vulnerability. It omits data for all uninhabited regions or regions where data were not available. Consequently, most of the Sahara is omitted from the analysis. Based on the combination of all four sources of vulnerability, the inhabited areas of the Sahel, and the entirety of Sudan are the most vulnerable areas in North Africa. The Algerian coast also exhibits high levels of vulnerability. Although Morocco and Tunisia are exposed to many of

the same climate threats, they appear less vulnerable due to better, though far still from good, governance.

Figure 9



PART 4: TAKING A CLOSER LOOK

Egypt and Sudan

More than one-third of Egyptians are employed in the agricultural sector, and nearly two-thirds of the poor inhabit rural areas. Many poor are dependent on agriculture and other related industries. Arable land resources are primarily confined to a narrow belt along the Nile River, which comprises less than five percent of Egypt's total land area. Except for the coastal regions along the Mediterranean and oases, the agricultural sector is nearly totally dependent on the Nile for irrigation and drainage. Water is extremely limited in Egypt, and one of the government's main priorities is to maximize the amount of water available and agricultural production. Following the completion of the Aswan High Dam in 1970, the Egyptian government began a program to expand irrigation systems along the Nile River.³⁸

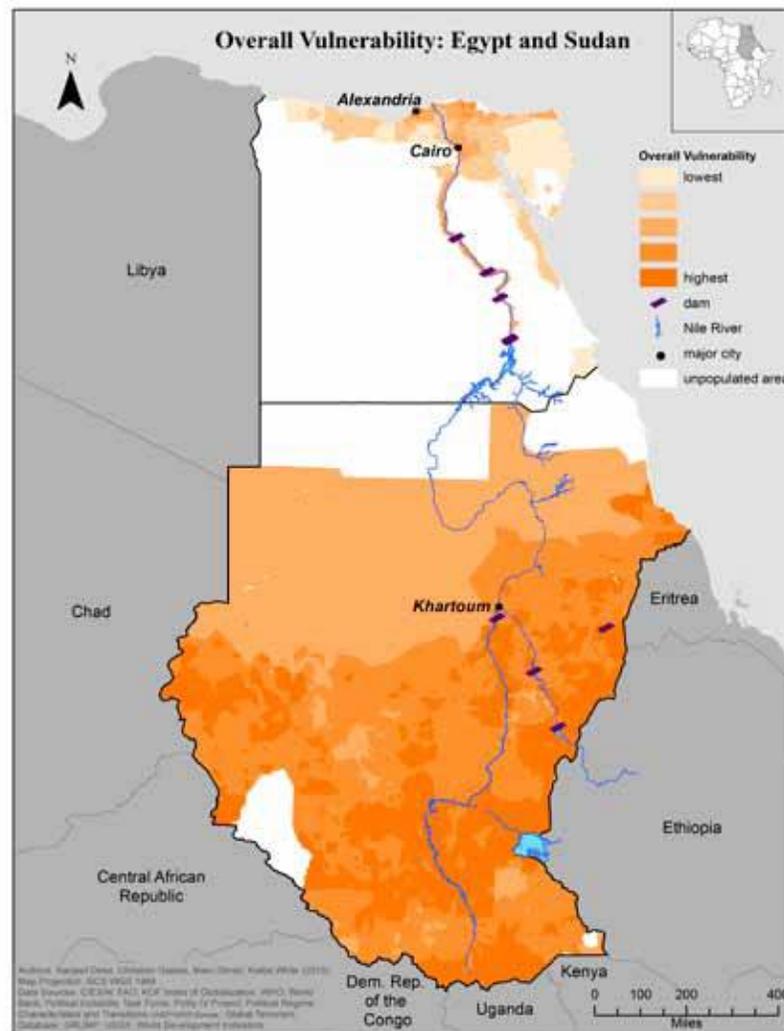
However, larger water supplies for irrigation lead to greater water logging and salinity, and decreased agricultural productivity. Egypt's government began a series of adaptation projects in 1970 as part of the National Drainage Program, which initiated reforms, implemented new technologies, and improved irrigation and drainage system management. More recently, the National Drainage Projects I and II have built upon the earlier drainage programs. The first drainage project that ran from 1992 to 2000 promoted agricultural productivity on 310,000 hectares by improving drainage and removing excess water. A key focus of the project was on improving technology and technical design, such as effective construction planning, management and quality control, and monitoring. Another component of the project was the creation of institutional and community mechanisms for systems maintenance, which involved organizing farmers into drainage associations.³⁹

The National Drainage Project II began in 2001 as a continuation of the first phase, and it is expected to be completed in 2013. The project objective is to improve agricultural productivity on an additional 336,000 hectares through improved drainage. The project also provides institutional

support and training to build the capacity of the Egyptian Public Authority for Drainage Programs. The second phase also works to improve the environment by addressing the discharge of untreated industrial and household sewage into open drains. Technical support has focused on improving drainage works design, construction planning and monitoring, and operation and maintenance of the system.⁴⁰

As in Egypt, internal water resources within Sudan are limited. Rainfall that is erratic and concentrated in a short season places Sudan in a vulnerable situation, particularly in rain-fed areas. Sudan also shares parts of its water basins—including the Nile, Lake Chad, and Rift Valley lakes—with neighboring countries.⁴¹ Historically, this positioning has put Sudan in direct conflict with other nations over water rights.

Figure 10



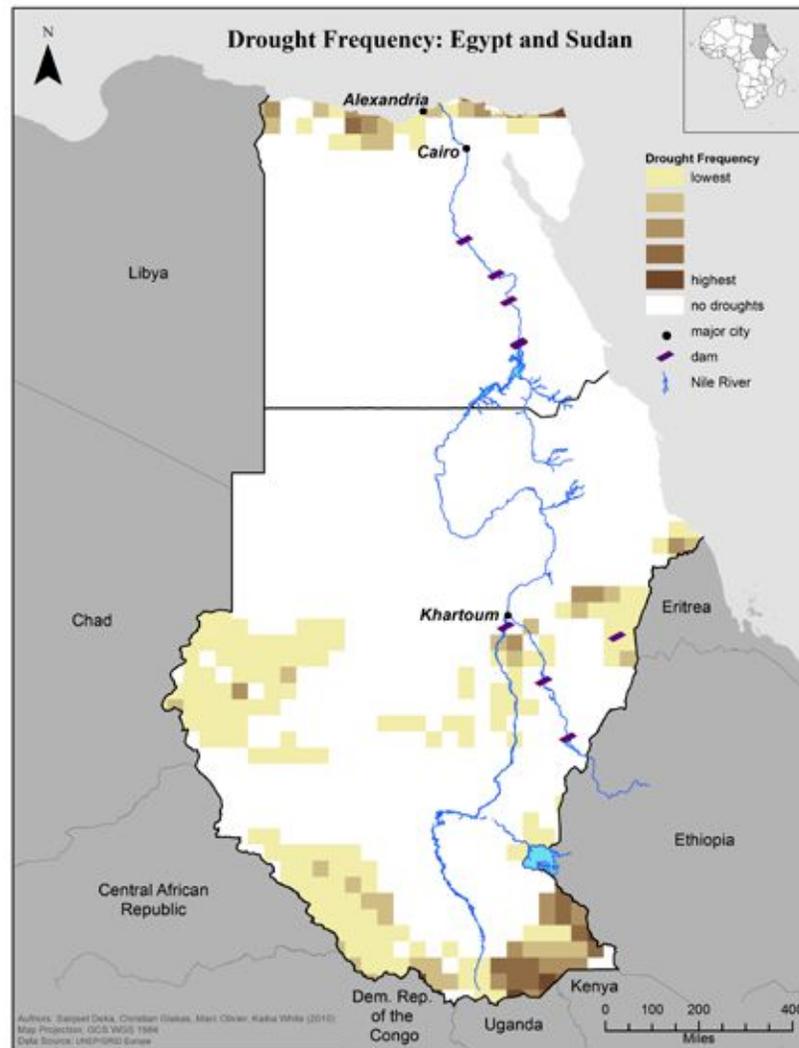
Overall vulnerability in Egypt and Sudan is driven primarily by poor governance (particularly in Sudan's case), population and migration concentrations, and physical exposure. In Egypt's case, its basis of physical exposure comes from its reliance on external water sources, low-lying coastal zones exposure, and in areas subject to drought and floods. Southern Sudan appears to be especially fire and drought prone. Sudan appears to be the most vulnerable country in North Africa, with the densely populated areas of the country falling in either the highest or second-highest level of overall vulnerability. The populated areas in the south, home to the disenfranchised African-Christian population, do not appear to be more vulnerable than the Arab areas around Khartoum.

Figure 11



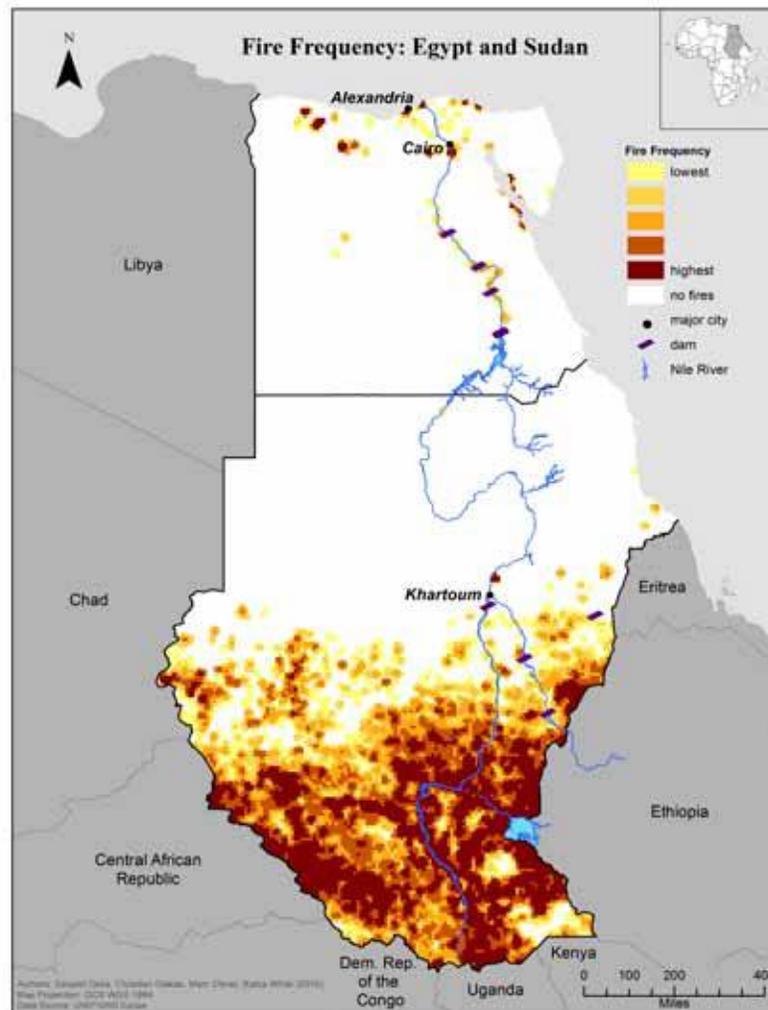
In the physical vulnerability basket, the relatively dark base color for Egypt and Sudan reflects low scores on national-level water indicators, suggesting that both countries are heavily dependent on water sources originating outside of their borders. Each country also uses a fairly high percentage of its available freshwater resources each year. Variations within countries depict sub-national climate hazard indicators, with darker pockets of color reflecting high vulnerability due to low-elevation coastal zones in northern Egypt and droughts and fires in southern Sudan.

Figure 12



Much of the darker variation in southern Sudan reflects incidents of drought and fire. Frequency of drought is depicted here. As noted in the methodology section, the importance of drought in this region prompted the study to weight droughts higher than other individual weather events in the Physical Vulnerability basket at 23.3 percent, compared to fire frequency, cyclone frequency, and floods, which were each weighted at 7.5 percent. This explains why the patterns of drought are more easily visible in the previous physical vulnerability map.

Figure 13



The southern part of Sudan suffers from the highest frequency of fires.

The Sahel

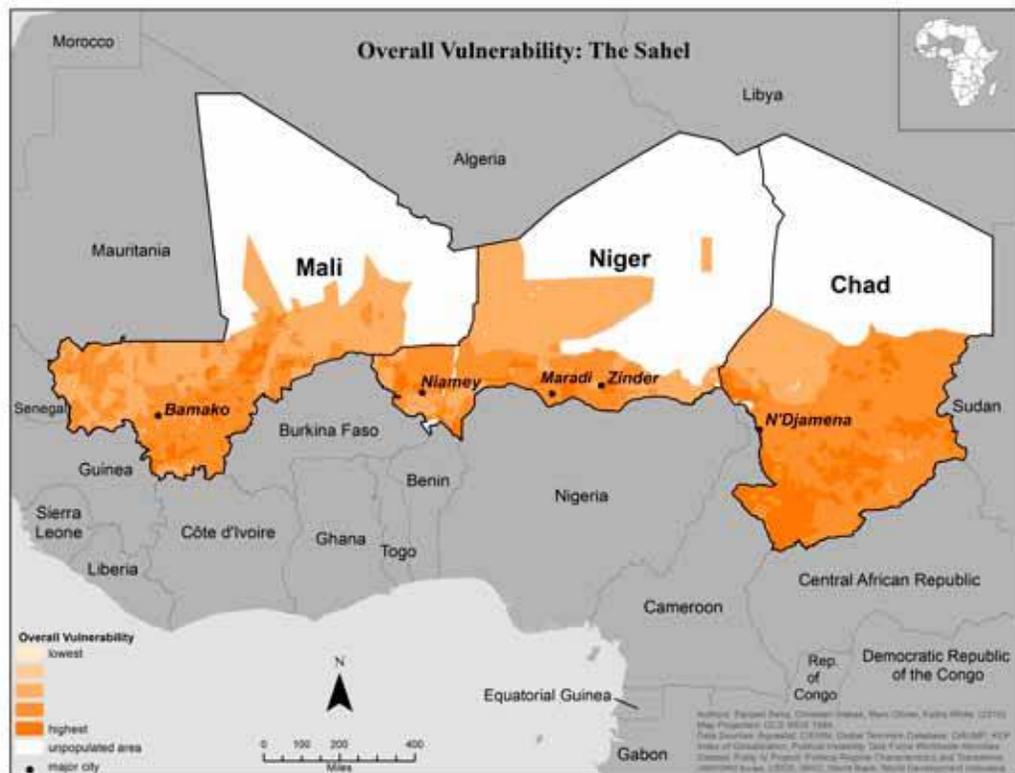
This study focuses on the central Sahelian countries of Chad, Niger, and Mali. The Sahel is a semi-arid belt in between the Sahara Desert and the wetter regions to the south. It spans the width of the continent, stretching from the Atlantic Ocean in the west to the Indian Ocean in the east. Rainfall variability is high in the region, generating widespread international concern over the impact of increased variability given the region's already dry and environmentally degraded lands. A major drought beginning in the late 1960s had a destructive and lasting impact on this ecologically vulnerable region.

Recent scientific studies have indicated that year-to-year changes in Sahel rainfall are forced by "changes in sea-surface temperature in the Gulf of Guinea (on the equator near the Prime Meridian) and by El Niño in the Pacific."⁴² Thus, when the Gulf Stream warms, "the Intertropical Convergence Zone shifts south away from the Sahel. This weather pattern reduces the African monsoon that draws moist air into the Sahel," causing the dry conditions.⁴³ In a recent example in 2010, a national survey in Niger showed that roughly 60 percent of the country's population was

running out of food after erratic rainfall stunted crop growth. Experts contend that, if the erratic rain flow continues, more than 1.5 million cases of malnutrition could be recorded there in the next five years.⁴⁴ With resources already stretched thin, desertification of the Sahel touches upon key human security considerations. Chief among them is population growth that is on track to outpace food supplies. Recent figures indicate that population in the region has doubled every 20 years.⁴⁵ Currently at around 260 million people, the growth rate of the population is expected to exceed the growth rate of food in the region. The problem is compounded by poor farming practices that result in overgrazing and soil erosion.

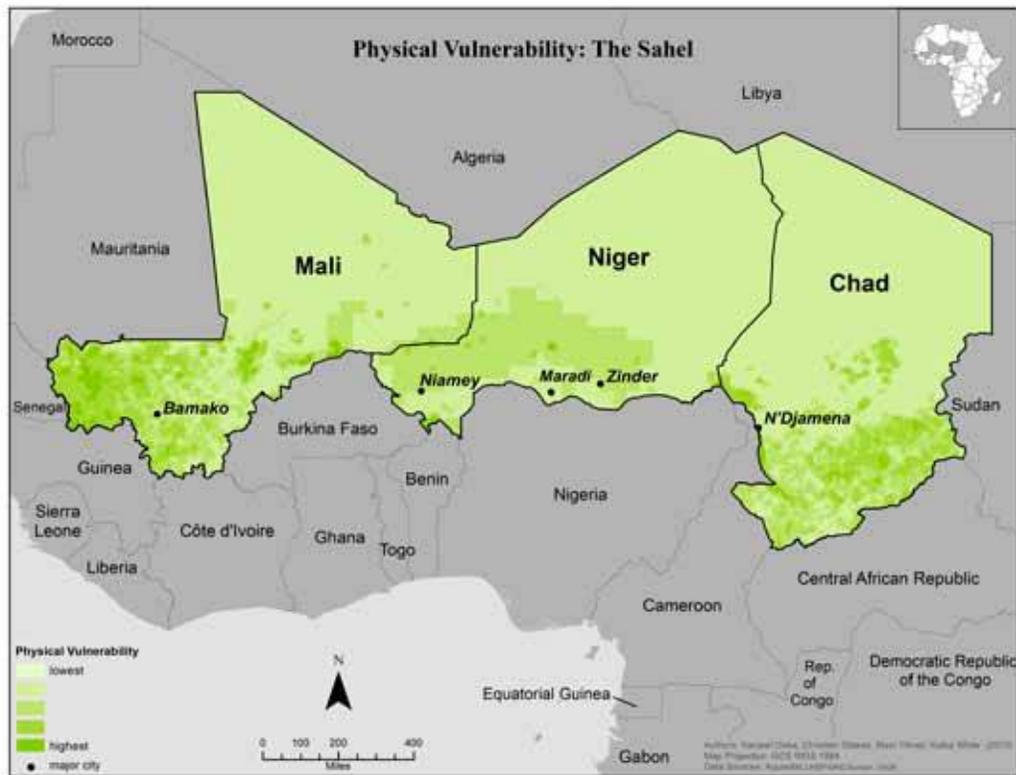
Another key consideration is how conflict and subsequent refugee flows could affect food security in the Sahel. Already, conflicts in Niger, Nigeria, Mali, and Darfur have caused floods of people from rural areas to seek shelter in refugee camps located in nearby countries. Such refugee flows can further tax food supplies and natural resources.

Figure 14



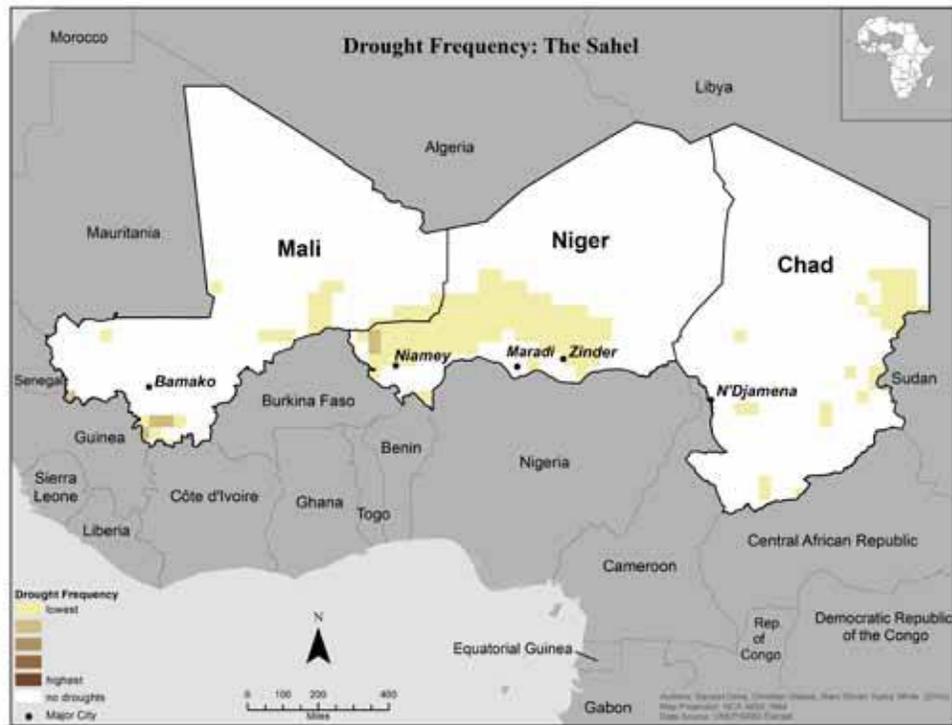
Overall vulnerability in the central Sahel stems primarily from poor governance, drought, wildfire risk, and population and migration risks. All three countries in the central Sahel meet this study's poverty and ethnic war thresholds indicating that incoming migration is a contributor to vulnerability. (Sudan is the only other country that met this requirement for North Africa.) Given that these countries possess poor levels of governance and are subject to in-migration vulnerability, it is no wonder that no single area in Mali, Niger, or Chad falls in the lowest vulnerability quintile.

Figure 15



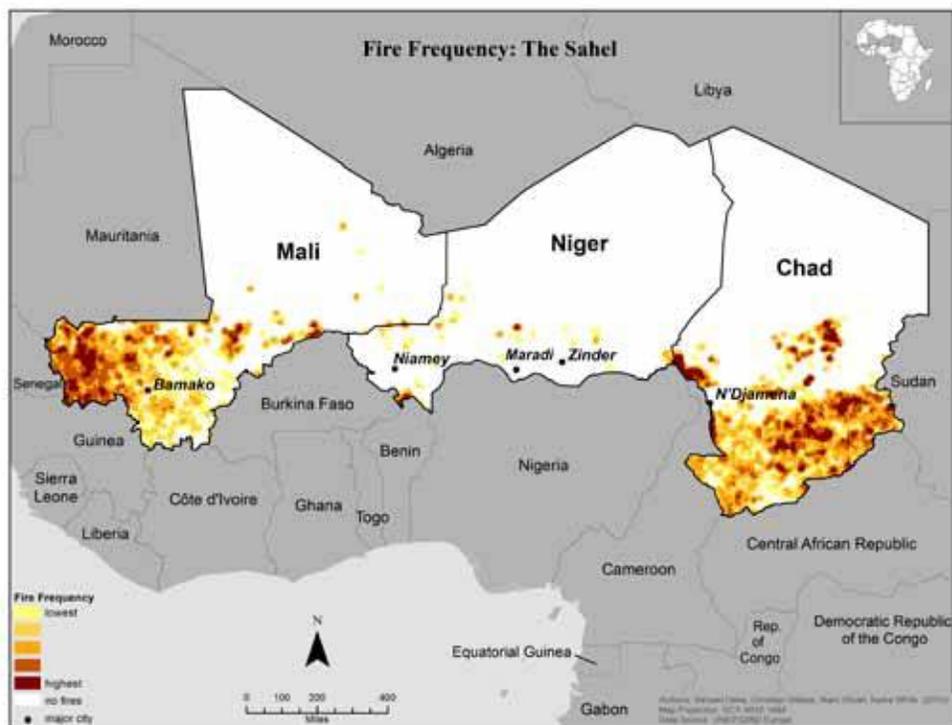
In the physical vulnerability basket, each of the Sahelian countries exhibits high vulnerability for water issues tracked at the national level, as displayed by the relatively dark base color. Sub-national variation is mainly caused by droughts and fires, shown in Figures 16 and 17.

Figure 16



Droughts in southern Mali and Niger, and in eastern Chad, are a main source of physical vulnerability in the Sahelian countries.

Figure 17



Fires in southern Mali and Chad are another key driver of physical vulnerability in the Sahel.

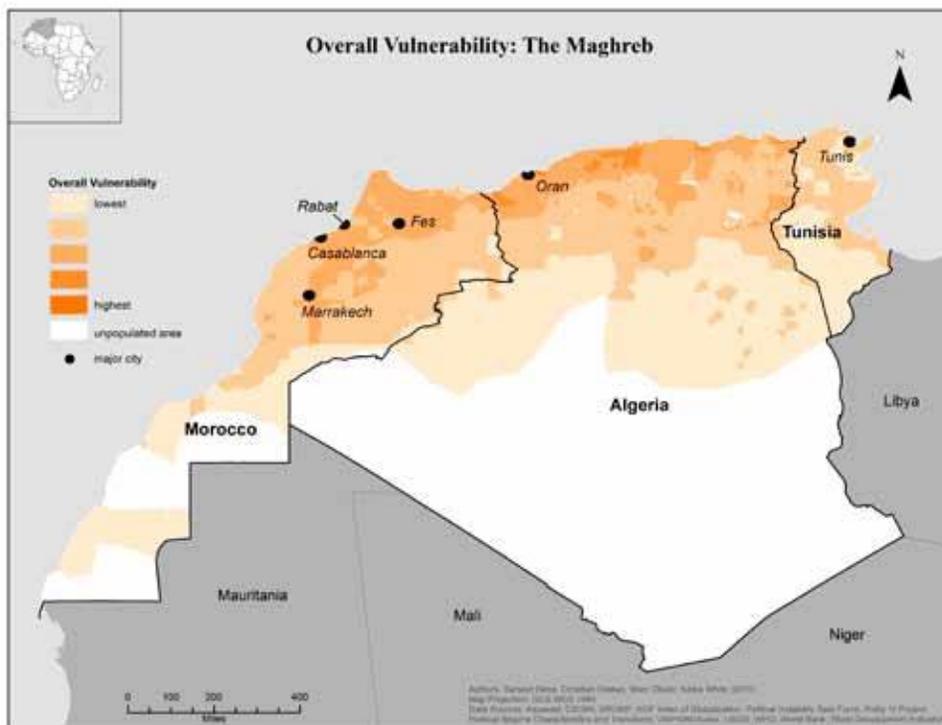
The Maghreb

The economies of Morocco, Algeria, and Tunisia are each highly dependent on agriculture and tourism—economic sectors that are particularly susceptible to the potential consequences of climate change. The agricultural sector consumes 85 percent of the region’s water supply, and rising sea-levels and over-drawing on aquifers threatens the region with groundwater salinization.⁴⁶ One of the most important issues is the need to efficiently manage water for agriculture use through options for reusing water, desalinization, and modernizing irrigation systems.

Water resource management is a significant concern as the countries in the Maghreb spend more than 20 percent of their budgets on water.⁴⁷ In addition, trans-boundary water management is also an issue since more than half of the region’s water flows across international borders. The World Bank estimates that environmental problems associated with water issues cost between 0.5 and 2.5 percent of the region’s GDP per year.⁴⁸

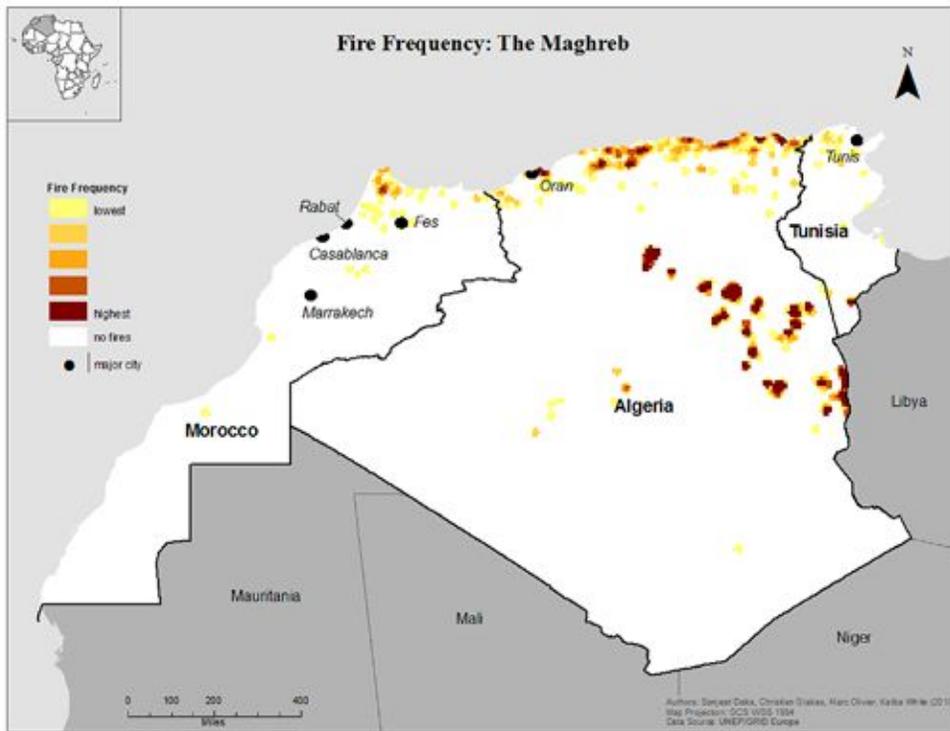
Furthermore, water services are not fully developed in rural areas or for urban poor populations. Contaminated surface and groundwater pose a significant threat to the environment and public health. Wastewater collection and treatment capacity is not always available, and the region will likely need to implement water reuse to meet growing demand.⁴⁹

Figure 18



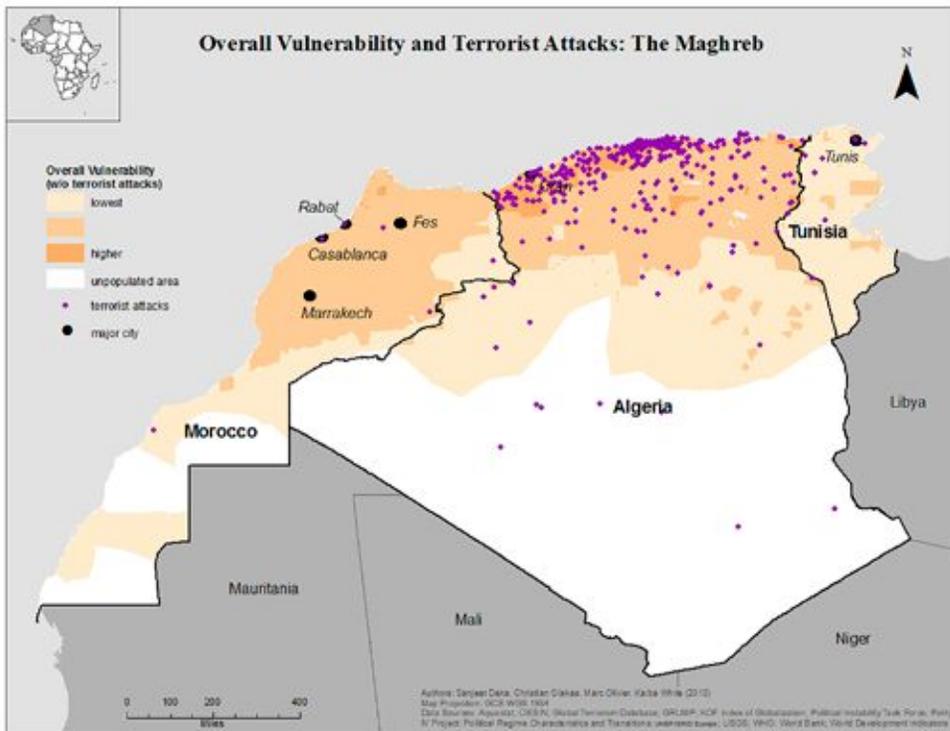
The highest vulnerability in the Maghreb is found on the Algerian coast, where, as revealed in the region-wide maps, high vulnerabilities to climate-related events, population, and terrorist attacks and conflict converge. Additionally, high levels of out-migration for both Morocco and Algeria, which both placed in the highest quintile for out-migration, contribute to higher levels of vulnerability throughout each nation (see Appendix E). None of these countries had sufficient levels of poverty or ethnic war to interpret incoming migration as increasing their vulnerability. Therefore, this variable can be discounted from the assessment of the Maghreb.

Figure 21



Countries in the Maghreb also have spotty exposure to wildfires.

Figure 22



In Figure 22, incidence of terrorist attacks across the Maghreb is overlaid on the overall vulnerability index that has had terrorist attacks removed as a vulnerability indicator. The vast majority of attacks take place in Algeria, whereas

Tunisia and Morocco appear largely free from attacks. Morocco and Tunisia scored well on the Governance and Political Violence indicators, placing in the least vulnerability quintile, whereas much of Algeria fell in the second lowest vulnerable quintile. This would suggest that the government in Algeria is less able to address security threats, a point that may be borne out by the terrorism data.

Geocoding the terrorist attacks enabled them to be merged into the Overall Vulnerability shapefile. The total number of attacks in each vulnerability quintile was then calculated, as well as the total combined geographic area within each quintile. For each polygon in a certain vulnerability quintile, the total number of attacks and the total area were summed, giving an aggregate number for each variable representative of all the geographical area of that vulnerability quintile. While a statistic regarding attacks per capita would offer further insight, the attacks per area statistic is helpful to gauge the accuracy of the vulnerability quintiles (see Table 5). Interestingly, the vulnerability quintiles and number of terrorist attacks per 1,000 km² are correlated. Although the first three vulnerability quintiles show very few attacks, vulnerability quintiles 4 and 5 show a dramatic increase in attacks, with 2.75 attacks per 1,000 km² in quintile 4, and 5.43 attacks per 1,000 km² in quintile 5.

Table 5. Terrorist Attacks in Overall Vulnerability Quintiles

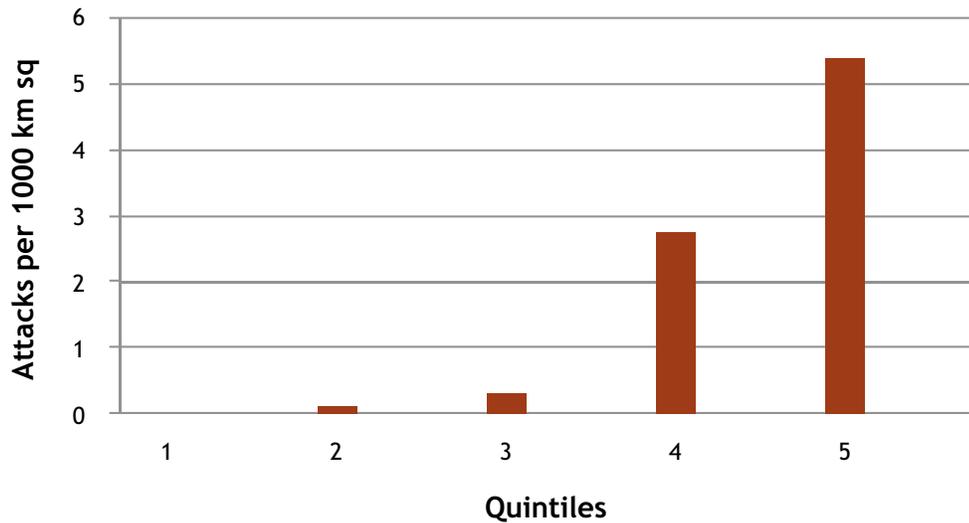
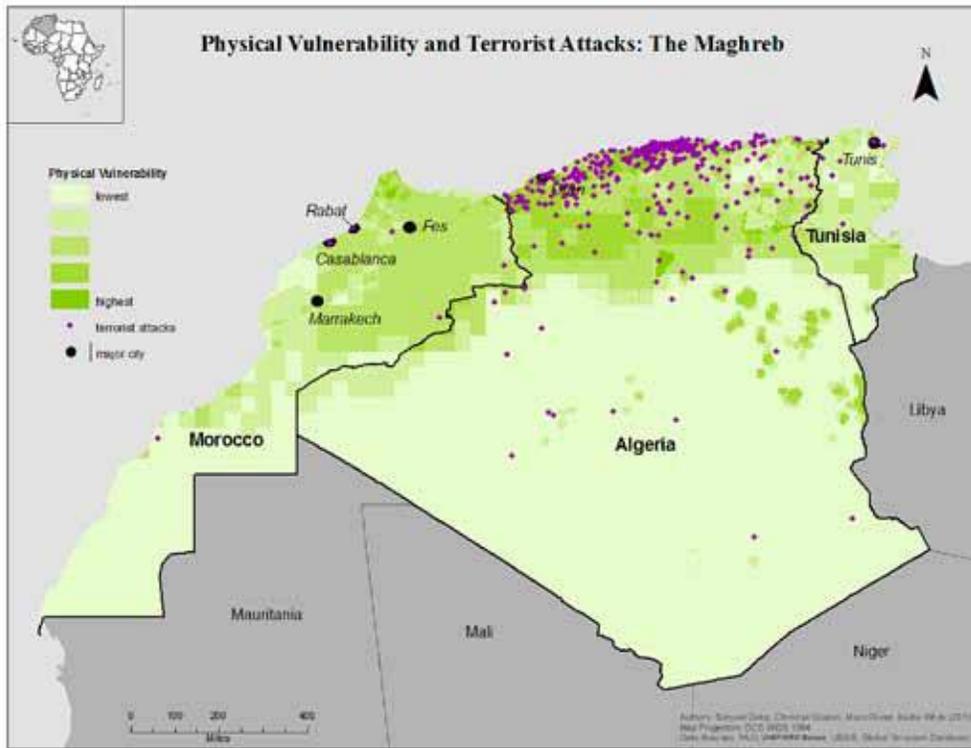
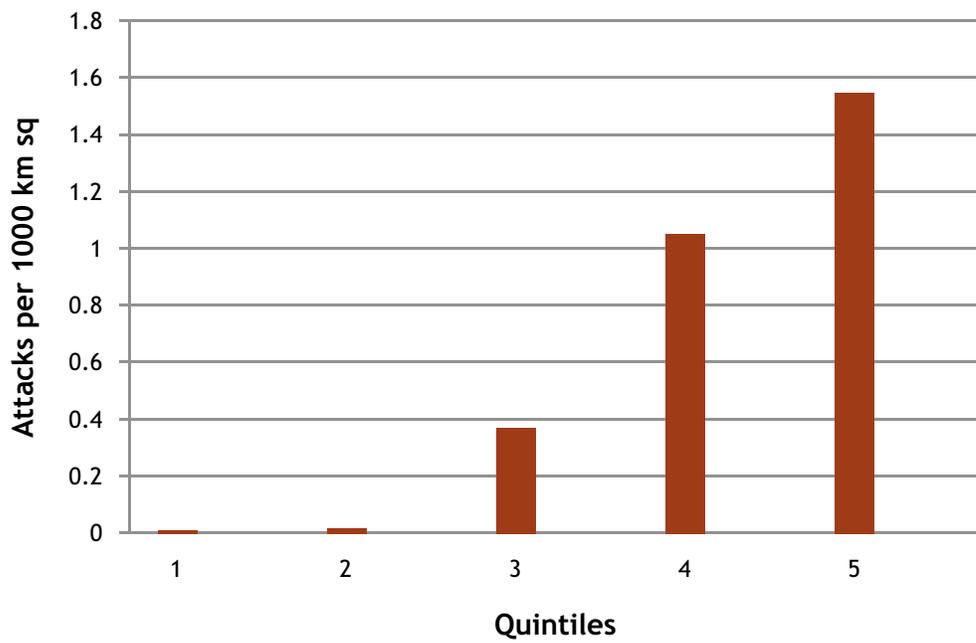


Figure 23



The team performed a similar analysis, summing the terrorist attacks per quintile of physical vulnerability. These results are shown in Table 6.

Table 6. Terrorist Attacks in Climate Vulnerability Quintiles



A positive correlation between terrorist attacks and the physical vulnerability quintiles was also found. Quintiles 1 and 2 show very few attacks per 1,000 km², but quintiles 3, 4, and 5 have 0.38, 1.06, and 1.54 attacks per 1,000 km², respectively. This is important since one could argue by the composite measure of vulnerability that terrorist attacks occur in the most populous areas. By contrast, the physical vulnerability data was largely collected independent of its impact on human populations (though one could argue that the water variables may be somewhat related to population).

PART 5: POLICY IMPLICATIONS

It is the hope of this study that the information here could help governmental agencies and international organizations decide where to focus their adaptation efforts. Based on the model and analysis considered here, the United States could work through the State Department, USAID, and international organizations to try and improve the level of governance in Mali, Niger, Chad, and Sudan. These four states do not currently have the ability to meet the specific climate threats that they are likely to face in the near future.

The northern states along the Mediterranean coast are better positioned to address the future effects of climate change. However, the terrorist threat facing Algeria may require Algiers to allocate substantial resources to address this threat, which may diminish resources available for future climate change adaptation efforts. The United States should enhance its efforts to help Algeria and other North African countries address the threat of terrorism through the Trans-Sahara Counterterrorism Partnership (TSCTP). The TSCTP is part of a broader U.S. effort under AFRICOM called Operation Enduring Freedom – Trans Sahara, which aims to increase regional security in Africa by addressing economic and social development, disaster preparedness, and medical emergencies.

While water security is an issue throughout the region, Mauritania, Mali, and Egypt are exceptionally dependent on water resources originating outside of their borders. The U.S. should work with the United Nations, the World Bank, and the International Monetary Fund to help improve water-use efficiency in these countries.

The aim of this study was to make some modest contribution to the growing dialogue about which African countries and sub-national areas could be most susceptible to the deleterious effects of climate change. As more sub-national data become available, future research efforts could pinpoint with even more granularity the most chronically vulnerable areas within African countries.

APPENDICES

Appendix A. Data Sources For Maps

Center for International Earth Science Information Network (CIESIN), *Gridded Population of the World (GPWv3) and the Global Rural-Urban Mapping Project (GRUMP)*, N.D., <http://sedac.ciesin.columbia.edu/gpw>.

Food and Agriculture Organization, *AQUASTAT*, 2009, www.fao.org/nr/water/aquastat/main/index.stm.

KEDS, *Political Instability Task Force Worldwide Atrocities Dataset*, 2009, <http://web.ku.edu/~keds/data.dir/atrocities.html>.

KOF, *KOF Index of Globalization*, 2009, <http://globalization.kof.ethz.ch/>.

Polity IV Project, *Polity IV Project: Political Regime Characteristics and Transitions, 1800-2008*, 2009, www.systemicpeace.org/polity/polity4.htm.

UNEP / UNDP / UN/ISDR / World Bank, *Global Risk Data Platform*, 2009, www.preventionweb.net/english/maps/index.php.

United States Geological Survey, *GTOPO30*, 2009, http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available/gtopo30_info.

United States Geological Survey, *Digital Atlas of Africa*, 2009.

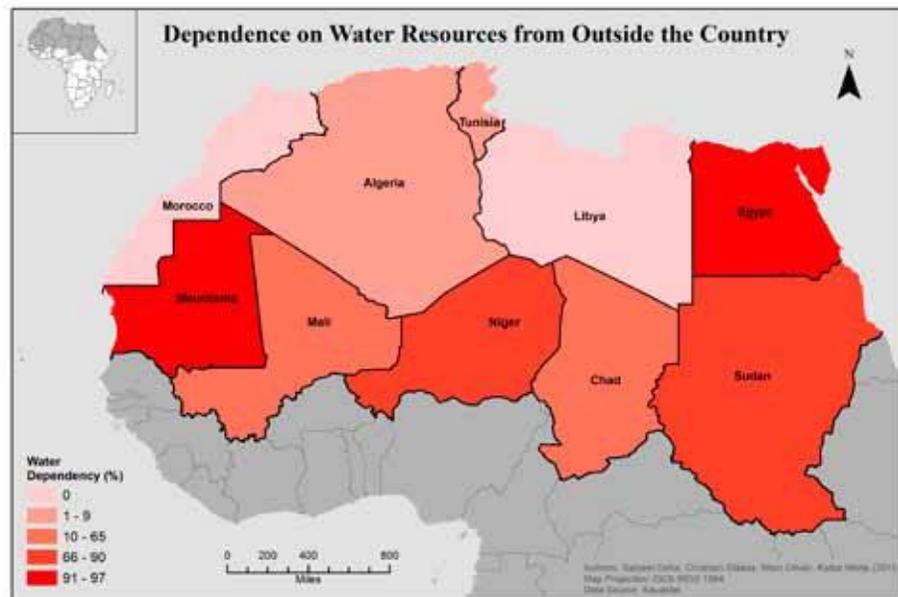
University of Maryland, *Global Terrorism Database*, 2009, www.start.umd.edu/gtd.

World Health Organization, *WHO Statistical Information System*, 2009, <http://apps.who.int/whosis/data/Search.jsp>.

World Bank, *Governance Matters 2009*, 2009, <http://info.worldbank.org/governance/wgi/index.asp>.

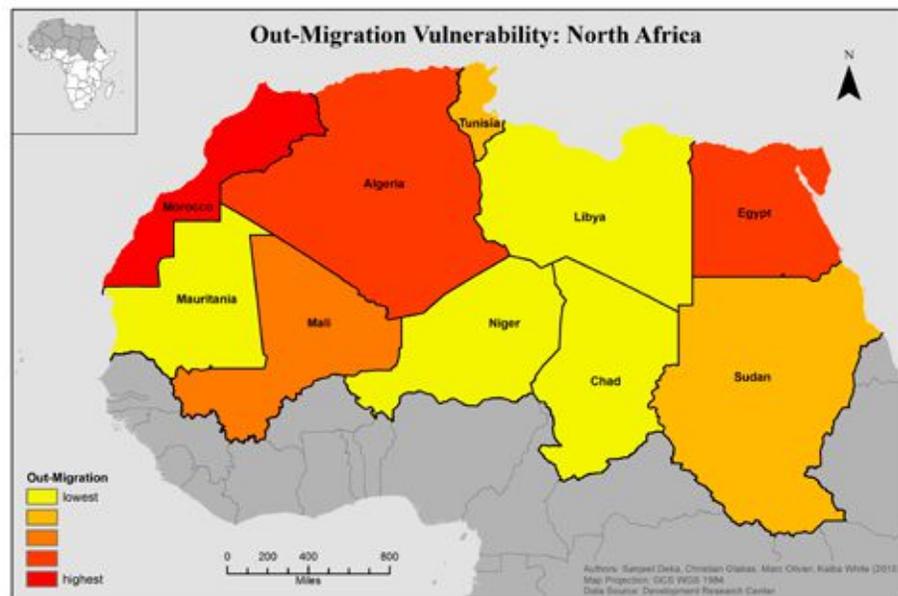
World Bank, *World Development Indicators*, 2009, <http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20398986~menuPK:64133163~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html>.

Appendix B. Dependence on Water Resources from Outside the Country



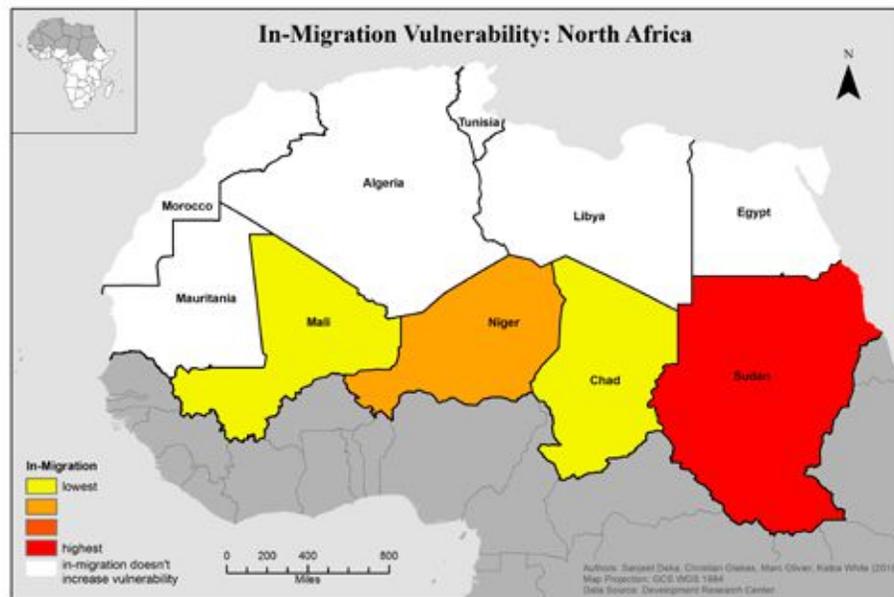
Egypt and Mauritania are most dependent on water resources outside of their borders.

Appendix C. Out-Migration Vulnerability of North Africa



Morocco, Algeria, and Egypt experience high levels of out-migration, which contributes to higher levels of vulnerability throughout each nation.

Appendix D. In-Migration Vulnerability of North Africa



Sudan experiences high levels of in-migration contributing to higher vulnerability in the country.

Appendix E. Use of Quintiles to Determine In-migration as a Driver of Vulnerability

African Countries	Ethnic War Quintile	Poverty Quintile	Ethnic War x Poverty	In-Migration Quintile	Out-Migration Quintile
Libyan Arab Jamahiriya	1	1	1	5	1
Seychelles	1	1	1		
Zimbabwe	1		1		
Algeria	1	2	2	2	5
Gabon	1	2	2		
Mauritius	1	2	2		
Tunisia	1	2	2	1	2
Botswana	1	3	3		
Cape Verde	1	3	3		
Egypt	1	3	3	1	5
Morocco	1	3	3	1	6
Namibia	1	3	3		
Sao Tome and Principe	1	3	3		
South Africa	3	1	3		
Cameroon	1	4	4		
Congo	1	4	4		
Djibouti	1	4	4		

African Countries	Ethnic War Quintile	Poverty Quintile	Ethnic War x Poverty	In-Migration Quintile	Out-Migration Quintile
Ghana	1	4	4		
Kenya	1	4	4		
Lesotho	1	4	4		
Madagascar	1	4	4		
Mauritania	1	4	4	2	1
Swaziland	1	4	4		
Tanzania (United Republic of)	1	4	4		
Benin	1	5	5		
Burkina Faso	1	5	5		
Eritrea	1	5	5		
Gambia	1	5	5		
Guinea	1	5	5		
Guinea-Bissau	1	5	5		
Liberia	1	5	5		
Malawi	1	5	5		
Mozambique	1	5	5		
Niger	1	5	5	3	2
Nigeria	1	5	5		
Senegal	1	5	5		
Sierra Leone	1	5	5		
Timor-Leste	1	5	5		
Togo	1	5	5		
Zambia	1	5	5		
Central African Republic	2	5	10		
Chad	2	5	10	1	1
Côte d'Ivoire	2	5	10		
Ethiopia	2	5	10		
Mali	2	5	10	1	4
Somalia	4	3	12		
Rwanda	3	5	15		
Angola	5	4	20		
Burundi	4	5	20		
Congo (Democratic Republic of the)	4	5	20		
Sudan	5	4	20	6	2
Uganda	5	5	25		

ENDNOTES

- ¹ This report utilizes data before the secession of southern Sudan. References to Sudan in this report refer to it as a unit rather than two separate countries, reflecting conditions at the time of writing.
- ² It is important to note that several indicators for Mauritania were missing, so there is less confidence in how vulnerable Mauritania is according to this model.
- ³ For the purposes of this paper, North Africa includes: Algeria, Chad, Egypt, Libya, Mali, Mauritania, Morocco, Niger, Sudan, and Tunisia.
- ⁴ Paul Krugman, "Droughts, Floods, and Food," *New York Times*, February 6, 2011.
- ⁵ Ban Ki Moon, "A Climate Culprit In Darfur," *Washington Post*, June 16, 2007.
- ⁶ National Intelligence Council and Office of the Director of National Intelligence, *Global Trends 2025: A Transformed World* (Washington: U.S. Government Printing Office, 2008).
- ⁷ Joshua W. Busby, Todd G. Smith, Kaiba White, and Shawn Strange, "Locating Climate Insecurity: Where Are the Vulnerable Places in Africa?" (Austin: Robert S. Strauss Center for International Security and Law, August 2010).
- ⁸ See Table 4 for a comprehensive list of variables included in the Vulnerability Index.
- ⁹ Central Intelligence Agency, *The World Factbook*, 2008.
- ¹⁰ Ali Agoumi, "Vulnerability of North African Countries to Climatic Changes," *International Institute for Sustainable Development* (2003), 1.
- ¹¹ *Ibid.*, 3.
- ¹² World Bank, "Middle East and North Africa," accessed April 15, 2010, <http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTWAT/0,,contentMDK:21634952~menuPK:4708988~pagePK:210058~piPK:210062~theSitePK:4602123,00.html>.
- ¹³ Agoumi, 1.
- ¹⁴ *Ibid.*
- ¹⁵ World Bank, "Middle East and North Africa."
- ¹⁶ "Al-Magreb" is the Arabic name for the country of Morocco. It is literally translated as "Land of the West" and it has historically referred to the Arab-inhabited lands West of Egypt. Today it is used to denote the countries comprising northwest Africa. In this study, the term will refer specifically to Morocco, Tunisia, and Algeria.
- ¹⁷ Agoumi, 3-4.
- ¹⁸ *Ibid.*
- ¹⁹ Aaron T. Wolf, "Conflict and Cooperation Along International Waterways," *Water Policy* 1 (2), 1998, 251-265, accessed June 1, 2011, www.transboundarywaters.orst.edu/publications/conflict_coop.
- ²⁰ Barry Malone, "Nile River Row: Could It Turn Violent?" *Reuters*, July 7, 2010.
- ²¹ Ahmed Eleiba, "Burundi Joins Nile Basin Pact Opposed by Egypt," *Ahram Online*, March 10, 2011, accessed June 1, 2011, <http://english.ahram.org.eg/NewsContent/1/64/7373/Egypt/Politics-/Burundi-joins-Nile-Basin-pact-opposed-by-Egypt.aspx>.
- ²² Duncan Miriri, "Kenya Signs Nile Basin Deal Rejected by Egypt," *Reuters*, May 19, 2011.
- ²³ Lester Brown, "When the Nile Runs Dry," editorial, *New York Times*, June 1, 2011.
- ²⁴ The Darfur conflict, as noted earlier, was controversially invoked by UN Secretary General Ban-Ki Moon as a climate conflict between herders and farmers. Academic researchers have also explored such links between climate stress and conflict. See Wolf, 251-265; Maywa Montenegro, "The Truth About Water Wars," *Seed Magazine*, May 14, 2009.
- ²⁵ Hein de Haas, "North African Migration Systems: Evolution, Transformations, and Development Linkages" (working paper, 2007), 2.
- ²⁶ The treaty includes Morocco, Algeria, Tunisia, and Egypt, but not Libya.
- ²⁷ Haas, 36.
- ²⁸ *Ibid.*, 10.
- ²⁹ *Ibid.*, 8.
- ³⁰ *Ibid.*, 10.
- ³¹ *Ibid.*, 14.
- ³² For a similar view, see Joshua Busby, Kaiba White, and Todd G. Smith, "Mapping Climate Change and Security in North Africa." *German Marshall Fund Climate and Energy Paper Series* (Washington: German Marshall Fund of the United States, October 2010).
- ³³ Joshua Busby et al., "Locating Climate Insecurity."
- ³⁴ If the terrorist attacks are incorporated into this vulnerability index, then they will cause the specific locations of the attacks to be deemed more vulnerable, and therefore more likely to be part of a higher vulnerability quintile. When the terrorist attacks are then aggregated by quintile, a higher number of attacks will naturally occur in the higher vulnerability quintiles. In other words, the relationship between terrorist attacks and vulnerability quintiles would be biased.
- ³⁵ A map displaying water dependency ratios is in Appendix A.
- ³⁶ Individual maps displaying in-migration and out-migration vulnerability are shown in Appendices B and C.
- ³⁷ Whereas the terrorist events are geo-coded to the precise location in which they occurred (or to the nearest city), political atrocities are attributed to the entire administrative unit in which they occurred.
- ³⁸ World Bank, "Egypt: National Drainage Project," accessed April 15, 2010, <http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTWAT/0,,contentMDK:21882386~menuPK:4724672~pagePK:210058~piPK:210062~theSitePK:4602123,00.html>.
- ³⁹ *Ibid.*
- ⁴⁰ *Ibid.*

⁴¹ "Sudan," AQUASTAT, accessed April 11, 2010, www.fao.org/nr/water/aquastat/countries/sudan/index.stm.

⁴² Robert Stewart, *Environmental Science in the 21st Century* (College Station: Texas A&M University College of Geosciences, 2008).

⁴³ Ibid.

⁴⁴ Foreign Policy Association, "UN Seeking \$133 Million to Combat Niger Food Crisis," April 8, 2010, accessed April 11, 2010, <http://foodcrisis.foreignpolicyblogs.com/2010/04/08/un-seeking-133-million-to-combat-niger-food-crisis>.

⁴⁵ Stewart.

⁴⁶ World Bank, "Middle East and North Africa."

⁴⁷ World Bank, "Accountability for Better Water Management Results," April 2008, accessed June 1, 2011, <http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/MENAEXT/MOROCCOEXTN/0,,contentMDK:21722173~pagePK:1497618~piPK:217854~theSitePK:294540,00.html>.

⁴⁸ World Bank, "Middle East and North Africa."

⁴⁹ Ibid.



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