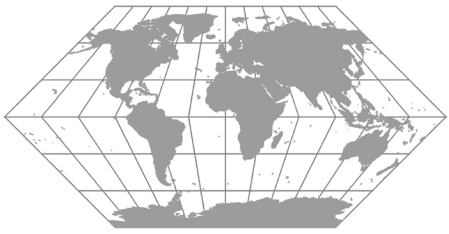
Modeling Environmental Security in Sub-Saharan Africa

Amy Richmond Krakowka
Department of Geography and Environmental Engineering
United States Military Academy
West Point, NY 10996
E-mail: amy.krakowka@usma.edu

Natalie Heimel
Department of Geography and Environmental Engineering
United States Military Academy
West Point, NY 10996

Francis A. Galgano
Department of Geography and the Environment
Villanova University
Villanova, PA 19085



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ABSTRACT

Many conflicts are enabled by environmental instability. This has been especially problematical in sub-Saharan Africa where non-sustainable practices and environmental change have combined with the proliferation of failing governments, enabling long-standing ethnic and religious antagonisms to erupt into violent conflicts. History has demonstrated that environmental stress can result in conflict, frequently along ethnic lines. Thus, the concept of environmental security has emerged as one basis for understanding conflict. To that end, this paper examines the nexus between the environment and conflict and demonstrates the need for careful environmental analysis by presenting a model illustrating the relationship between natural resources and political stability in Sub-Saharan Africa. The results suggest that a statistically significant relationship exists between arable land and access to fresh water, and political stability and non-violence.

Key Words: ethnic conflict, environmental security, military geography, resource scarcity, Rwanda

INTRODUCTION

History and contemporary events have demonstrated that environmental stress often results in conflict, frequently along ethnic schisms (recent examples include Chiapas, Rwanda, Somalia, and Darfur). This reality is exacerbated by population pressure, resource shortages, environmental change, and natural hazards. Evidence suggests that this trend will persist because environmental change will continue to stress marginal environments, especially in places with weak governance, making clear the relationship between regional stability and environmental factors (Butts 1994; Homer-Dixon and Levy 1995).

Non-sustainable environmental practices, migration, and resource shortages, which are common in developing states, may further

de-stabilize states with weak governance (Schwartz and Randall 2003; Gleditsch et al. 2007). These regions are defined by endemic imbalances in the distribution of wealth, staggering health problems, fragile political systems, regressive social systems, and disenfranchised youth susceptible to the lure of extremism, thus making conflict more likely. We do not contend that the nature of modern conflict is new: in fact, insurgency, ethnic clashes, and civil war are ancient modes of warfare. We do maintain, however, that increased levels of environmental stress are enabling a surge in the frequency of conflicts with an environmental component. Furthermore, we contend that this is not a simple, deterministic relationship. Indeed, environmentally triggered conflict is fueled by dynamic, complex, and interacting processes; thus, a framework for analysis is necessary to understand causes and consequences.

With conflicts in Somalia, Bosnia, Darfur, Rwanda, East Timor, and Kosovo as the precedent, the use of Western and United Nations (U.N.) military force to address humanitarian dimensions of regional conflict has been now well established (Dulian 2004). Conflicts with an environmental component coupled with divisive ethnic dimensions, such as those observed in Rwanda, have increased pressure on the West and the U.N. to commit resources to stability efforts (Drapeau and Mignone 2007).

In fact, strategic policy documents produced by the U.S. National Security Council (NSC) and Department of Defense (DoD) have delineated U.S. strategic interests in environmentally enabled instability. The environment first became an element in the U.S. National Security Strategy in 1991, when the NSC pointed out that, "stress from environmental challenges is already contributing to political conflict" (NSC 1991, 2; Butts 1994). By 2005, the DoD identified environmentally related instability as a fundamental strategic concern because evidence suggested that environmental stress is an important contributor to contemporary conflicts. Furthermore, environmental conflict typically manifests itself along ethnic lines, thus making its international management difficult (DoD 2005). With continued environmental destabilization in weaker states and the exploitation of ungoverned spaces by violent transnational actors, government leaders and military commanders as well as directors of non-governmental organizations and intergovernmental bodies will have to deal with humanitarian disasters and ethnic violence. Hence, a framework for analysis can be a useful tool to articulate and delineate the fundamental causes of environmentally triggered violence. To that end, this paper examines the nexus between the environment and conflict and demonstrates the need for careful environmental analysis by presenting findings for a model illustrating the relationship between natural resources and political stability. The results suggest that a statistically significant relationship exists between arable land and access to fresh water, and political stability and non-violence.

For our analysis, we propose a comprehensive definition of environmental security, which is consistent with links between people, governance, and environmental stressors. We view environmental security as a process involving environmental risk analysis based on multifaceted linkages between anthropogenic and natural processes that destabilize the environment and contribute to instability or conflict. The fundamental components of environmental security include: 1) environmental processes that undermine governments and promote instability; and 2) environmental processes that trigger civil conflict.

THE ENVIRONMENT, SECURITY, AND CONFLICT

The incidence of environmentally triggered conflict is not new. For example, compelling evidence suggests the role of environmental stress in precipitating warfare in ancient China and the collapse of the Anasazi and Akkadian civilizations (Gibbons 1993; Abate 1994; Diamond 2005; Mays 2007; Zhang

et al. 2007). Recent examples in Chiapas, Rwanda, Somalia, and Darfur seem to indicate the nexus of environmental stress and violent conflict is a modern reality and that the specter of contemporary environmental change and resource scarcity may prompt an escalation in violent conflict (Homer-Dixon 1999; Klare 2001; Schwartz and Randall 2003).

Environmental stress alone does not necessarily trigger violent conflict. Evidence suggests that it enables violent conflict when it combines with weak governance and social fragmentation, to affect a spiral of violence, typically along latent ethnic and political divisions. Furthermore, the spatial distribution of contemporary environmental stress is pervasive, but not uniform; and modern trends indicate that environmentally driven violence has been concentrated in the developing world and regions with extreme social fragmentation and stratification (Homer-Dixon 1999; Gleditsch et al. 2007). Developing states are more susceptible to environmentally triggered violent conflict because they are, characteristically, more dependent on the environment for their economic productivity, have higher concentrations of subsistence farming, burgeoning population and manifest weak governance (Homer-Dixon 1999; Galgano 2007).

Weak governance is a seminal problem in the developing world and since 1990, the number of failing states has increased (Francois 2009; Failed States Index 2010; Galgano and Krakowka 2010). Table 1 indicates the 25 most poorly governed states in the world according to the World Bank (Kaufmann et al. 2008) along with comparative rankings from other leading governance indicators. The World Bank index suggests that 11 of the 25 most weakly governed states are in sub-Saharan Africa, which is by far the largest concentration in any region. Data from the other leading governance indices suggest a remarkable level of fidelity in the identification of failed or failing states.

The World Bank (Kaufmann et al. 2003, 2008) examined governance by indexing six key metrics (voice and accountability of the government; political stability and absence of violence; government effectiveness; regulatory quality; rule of law; and control of corruption) as a means of quantifying the level of state stability. Their 2003 findings suggest that of 187 states examined, 92 (49 percent of all states) exhibit chronic political instability and can be categorized as failing states.

Although World Bank data (Kaufmann et al. 2008) suggest that overall levels of governance, worldwide, have improved marginally, there are still some disturbing trends. First, government stability in developing regions such as sub-Saharan Africa, South America, and Asia is growing weaker. Second, the disparity between the developed and developing world is growing, and finally, the 2008 data indicate that while globally scores have marginally improved, the number of failing states has increased. Of the 212 state entities examined, 122 exhibit significant levels of political instability—57 percent of all states (Kaufmann et al. 2008).

The large number of failed or failing states in sub-Saharan Africa is troubling because they have large areas that are outside of effective government control and thus, can be affected severely by humanitarian disasters, environmental stress, and ethnic conflict (Galgano 2007). Pervasive political instability and a lack of government control generally means that these states characteristically lack effective institutions and the financial and material resources to mitigate the effects of non-sustainable practices that degrade the environment or safeguard the population from the effects of environmental stress. They are more vulnerable to the consequences of environmental stress and typically suffer from four causally related social effects: 1) reduced agricultural production; 2) economic decline; 3) population displacement; and 4) civil disruption (Homer-Dixon 1999; Galgano and Krakowka 2011). This raises the complexity of the problems faced by external governmental and non-governmental relief agencies as they try to develop relief plans. Thus, an

Table 1. Level of Governance 1996 – 2002 and Key Environmental Indicators.

[1] Aggregate governance index derived from Kaufmann, Kraay, and Mastruzzi (2003). This index was developed by an examination of six metrics (i.e., voice and accountability of the government; political stability and absence of violence; government effectiveness; regulatory quality; rule of law; and control of corruption) during four periods between 1996 – 2002. A more negative score indicates weaker governance.

State (Rank) 1	Governance Index [2]	Human Development Index [3]	World Governance Index [4] (Rank)	Failed States Index [5] (Rank)	Corruption Index [6]	Democracy and Governance [7]
Somalia (212)	-2.60	NO DATA	0.290 / 179	114.3 / 1	1.1	7.55
North Korea (211)	-1.74	NO DATA	0.423 / 175	97.8/ 19	NO DATA	7.36
Myanmar (210)	-1.68	0.586	0.446 / 173	99.4 / 16	1.4	7.88
Afghanistan (209)	-1.64	0.352	0.511 / 153	109.3 / 6	1.4	7.84
D.R. Congo* (208)	-1.58	0.389	0.419 / 177	109.5 / 5	2.0	7.60
Zimbabwe* (207)	-1.56	0.112	0.461 / 172	110.2 / 4	2.4	6.87
Sudan (206)	-1.49	0.531	0.417 /173	111.8 / 3	1.6	7.69
Iraq (205)	-1.48	0.098	NO DATA	107.3 / 7	1.5	7.61
Chad (204)	-1.47	0.392	0.436 / 174	113.3 / 2	1.7	6.95
Equatorial Guinea* (203)	-1.40	0.719	0.514 / 156	88.5 / 44	1.9	7.18
Guinea* (202)	-1.37	0.435	0.546 / 143	105.0 / 9	2.0	6.27
C. African Rep.* (201)	-1.36	0.369	0.461 / 171	106.4 / 8	2.1	6.56
Turkmenistan (200)	-1.32	0.369	0.508 / 159	84.3 / 59	1.6	7.30
Ivory Coast* (199)	-1.31	0.484	0.489 / 164	101.2 / 12	2.2	7.25
Haiti (198)	-1.25	0.532	0.488 / 166	101.6 / 11	2.2	7.20
Eretria (197)	-1.24	0.472	0.488 / 165	93.3 / 30	2.6	6.93
Angola* (196)	-1.22	0.564	0.482 / 167	85.0 / 55	1.9	6.76
Guinea Bissau* (195)	-1.18	0.396	0.518 / 155	97.2 / 22	2.1	6.50
Venezuela (194)	-1.18	0.844	0.602 / 110	79.5 / 77	2.0	6.02
Congo* (193)	-1.16	0.601	0.559 / 138	93.1 / 30	2.1	6.71
Uzbekistan (192)	-1.13	0.710	0.571 / 129	90.5 / 36	1.6	7.17
Liberia* (191)	-1.11	0.442	0.472 / 170	91.7 / 33	3.3	7.39
Cambodia (190)	-1.08	0.593	0.570 / 133	88.7 / 42	2.1	6.21
Burundi* (189)	-1.07	0.394	0.501 / 161	96.7 / 23	1.8	7.28
Laos (188)	-1.06	0.619	0.560 / 137	88.7 / 40	2.1	7.05

[1] An asterisks indicates a Sub-Saharan State. Rankings derived from governance indicators developed by the World Bank (Kaufmann et al. 2008). Indicates rank among 212 state entities.

[2] Aggregate governance index derived from Kaufmann et al. (2008). This index was developed by an examination of six metrics (i.e., voice and accountability of the government; political stability and absence of violence; government effectiveness; regulatory quality; rule of law; and control of corruption) between 1996 – 2008. A more negative score indicates weaker governance.

[3] Human Development Index (U.N. 2011) provides a composite measure of three dimensions of human development: life expectancy, adult literacy, and standard of living. See http://hdr.undp.org/en/. Higher numbers equate to a more favorable index. Scores below 0.5 indicate poor human development.

[4] The World Governance Index (Francois, 2009) provides indicators and an index that ranks 179 state entities. The index ranks states from 0.0 (poorly governed) to 1.0 (well governed).

[5] The Failed States Index (2011) ranks 178 state entities. In this index, the higher score indicates governance that is more problematic.

[6] The Corruption Perception Index (Transparency International 2010) ranks states according to perception of corruption in the public sector—an aggregate indicator that combines various sources. States are ranked between 10.0 (no corruption) and 0.0 (pervasive corruption).

[7] Democracy and Governance Index (Country Indicators for Foreign Policy, 2007) uses and index to indicate levels of governance. The index is developed from an assessment of: government accountability, security and fundamental rights, regulatory enforcement, and access to justice.

effective framework for understanding the nature of the conflict and its environmental underpinnings can serve as a useful tool to assist those organizations as they try to develop plans to mitigate the causes of environmental stress and associated conflict (deMenocal 2001).

ENVIRONMENTAL CONFLICT: CAUSES AND RESULTS

Environmental stress may play an expanding role in future conflicts because the economic well-being of about one-half of the world's population is tied directly to the land, and projected population growth and climate change threaten to increase the strains on these populations. Nearly 2 billion people already do not have access to clean drinking water (Gleick 2008), and nearly 75 percent of the world's most impoverished inhabitants are subsistence farmers attempting to live on increasingly smaller plots of land. Drought, desertification, deforestation, and soil erosion and exhaustion are major problems in these regions. These are compounded by the fact that although agricultural space, biomass fuels, and water are renewable resources, in many places non-sustainable practices are depleting them far beyond their renewal capacity (Homer-Dixon 1999). Although the consequences of these events are primarily felt at the local-scale, they do have the potential to trigger major regional wars over declining resources (Homer-Dixon 1999; Drapeau and Mignone 2007).

A FRAMEWORK FOR ANALYSIS

Since 1990, violent conflicts have occurred in Afghanistan, Bosnia, Kosovo, Croatia, Rwanda, Ivory Coast, Burundi, Angola, Nigeria, Sudan, Turkey, Azerbaijan, Georgia, Kashmir, Myanmar, Sri Lanka, Iraq, and Palestinian Territories (Kaufman 1996; Renner 2002; Busby 2005). It would be too simplistic, and probably incorrect, to assert that environmental stress instigated each of these conflicts, and too difficult to disaggregate their human and environmental components because they are interrelated and complex. Therefore, if we attempt a proactive approach to detect and perhaps mitigate environmentally enabled conflict, it is useful to develop an analytical framework from which we can make informed assessments (Butts 1994). This framework must account for anthropogenic and natural environmental processes and recognize fundamental ethnic, economic, cultural, and political issues behind regional instability, understanding that each place is different (Homer-Dixon 1999).

Thus, we propose a framework for conflict analysis that identifies sources of environmental stress and linkages to political, cultural, economic, and ethnic dimensions. Our framework is developed after the work of Butts (1994), Percival and Homer-Dixon (1995), Homer-Dixon (1999), and Diamond (2005). The framework is not intended to be predictive or proscriptive, only an analytical tool to account for dynamic and complex factors that contribute to environmentally enabled conflict.

The framework (Fig. 1) is not a checklist because such inventories tend to disconnect intrinsically linked factors into artificially discrete variables. Instead, the framework forms the basis for a narrative explaining links between environmental stress and conflict. The framework suggests that environmentally enabled conflict evolves from four fundamental processes. These processes form the basis of our framework and are not mutually exclusive: they take place concurrently, and occur at the intersection of the natural landscape and human activity. So too are the possible outcomes we have identified. This framework is an analytical tool which can help identify areas that are at risk of environmentally aggravated conflict. If a region is experiencing one or more of the destabilizing processes then one can expect one of the outcomes to occur.

An examination of the Rwandan genocide is an informative study because it embodies nearly all of the fundamental environmental security challenges extant in sub-Saharan Af-

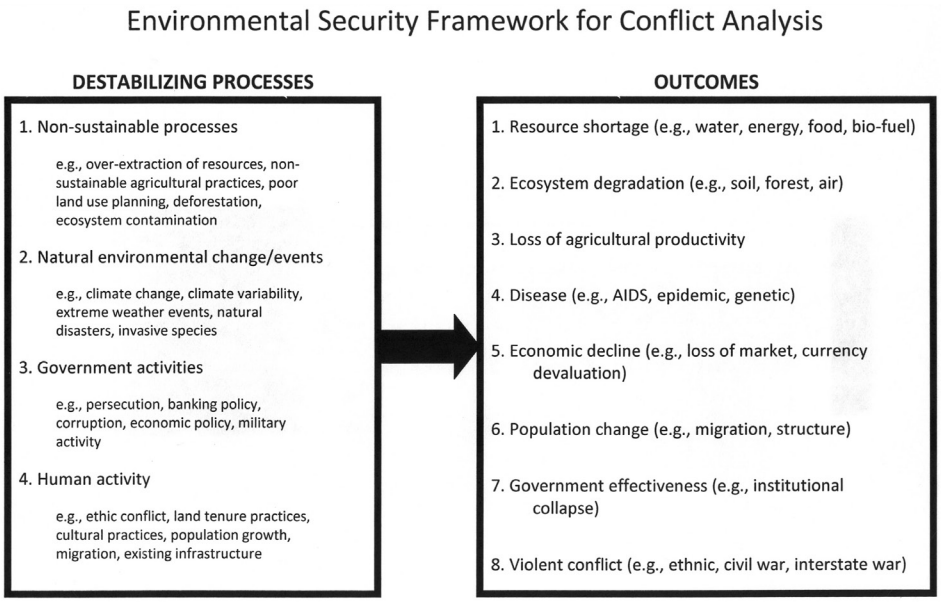

Figure 1. The environmental security framework for conflict analysis.

rica. The salient variables that triggered ethnic violence in Rwanda were non-sustainable environmental practices, drought, decreased agricultural output, and economic collapse, which destabilized Rwandan society, exacerbating ethic divisions, and eroded the government's ability to sustain a secure living environment (Percival and Homer-Dixon, 1995; Dulian, 2004). Estimates put the death toll between 800,000 and 1,000,000, or about 75 percent of the Tutsi population and about 11percent of Rwanda's population (Newbury, 1995). Perhaps the most important environmental stressor in Rwanda was its population density and the spiral of ecosystem degradation it caused. Rwanda (Fig. 2), has the highest population growth in the world, averaging about 4.1percent, with a doubling time of 17 years. Rwanda is the most densely populated state in Africa: its 1995 population was about 7.5 million (Percival and Homer-Dixon 1995).

Agricultural potential in Rwanda is high because its volcanic soils are fertile, and the geologic structure establishes conditions for a sustainable groundwater supply. Therefore, sustainable farming practices should permit Rwandans to produce crops to support a growing population (Mitchell 1997; Diamond 2005). However, by 1994, population growth and non-sustainable farming practices dangerously degraded the environment by reducing soil productivity, and consequently diminished food output beyond sustainable levels. Rwanda's population growth meant that there was little useful arable land left for cultivation. Additionally, about one-half of all farming in Rwanda is conducted on hill slopes greater than 10 degrees. Over cultivation and cultivation on marginal land led to accelerated erosion and decreased soil fertility (Clay et al. 1998). Consequently, Rwanda was transformed from one of the region's leading producers in *per capita* food production in 1980, to one of its worst by 1990. Although total food output increased by 10 percent between 1980 and 1990, *per capita* production declined nearly 20 percent (Percival and Homer-Dixon 1995).

The environmental underpinnings of Rwanda's environmental degradation are associated with a series of non-sustainable land use practices, which were underscored by a decade-long drought. By 1990, Rwanda

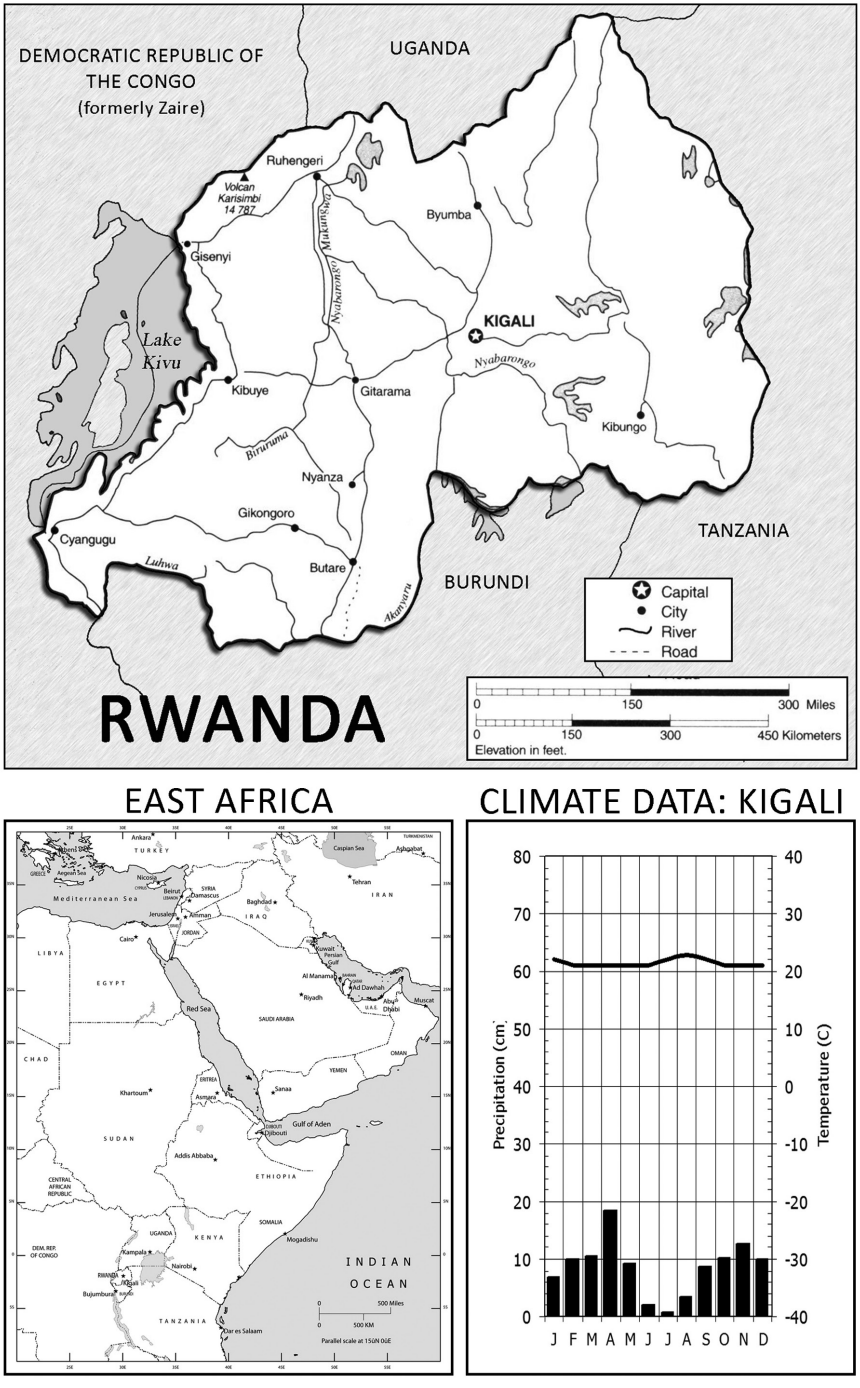

Figure 2. Map of Rwanda and East Africa.

had experienced 15 years of relative calm and prosperity. However, the steep decline in world coffee and tea prices, destabilized the economy. The second factor was non-sustainable land use practices that over-stressed the environment. A drought affected East Africa, and Rwanda in particular in the early 1990s, during which rainfall totals declined by as much as 30 percent, but more importantly, the drought revealed a set of fundamental environmental land use problems, namely deforestation, soil erosion, and soil exhaustion (Newbury 1995; Diamond 2005).

Rwanda's subsistence farmers were increasingly pushed into marginal land. Thus, by 1985, all arable land in Rwanda was under cultivation (Percival and Homer-Dixon 1995). Forests were clear-cut, exposing slopes to runoff and erosion, limiting the percolation of precipitation into the ground water table. Fallow periods were shortened resulting in soil exhaustion. Deforestation led to severe soil erosion and a lowering of the water table to the extent that streams began to run dry. Thus, when the climate began to change into a decadal drought cycle, the ability to irrigate was lost (Mitchell 1997).

Rwanda had a large, densely concentrated population that depended on the land for resources that were rapidly diminishing resulting from non-sustainable practices, population pressure, and environmental change. About 90 percent of Rwandans were engaged in subsistence agriculture on increasingly smaller plots of land with declining productivity and by 1994, population had clearly outpaced food production (Diamond 2005). These environmental factors, combined with the collapse of the global coffee market, latent ethnic problems and political competition pushed this society over the edge.

Rwanda provides a historical case study of how our environmental security framework can be used. We believe that by further developing our framework and modeling environmental variables we can gain greater insight into environmental security issues in sub-Saharan Africa.

ENVIRONMENTAL SECURITY IN SUB-SAHARAN AFRICA[1]

Environmental security—or insecurity—in sub-Saharan Africa must be considered in terms of numerous complex and non-linear interactions between a broad range of factors including large populations, poor infrastructure, latent ethnic conflict, pervasive endemic diseases, fragile ecosystems, weak governance, and the growing specter of climate change and its attendant environmental consequences. Sub-Saharan Africa is susceptible to a broad array of environmental security concerns, perhaps more so than any other region—and given its fragmented social and cultural landscape, it is most vulnerable to violent conflict (Bennett 1991; Goodman 2007; Klare 2001). Of the 43 countries in sub-Saharan Africa, 29 suffered from civil conflict during the 1980s and 1990s (Miguel et al 2004). This resulted in millions of displaced people (Sambais 2001). The U.N.'s Environmental Programme (UNEP) indicated that sub-Saharan Africa has the lowest human development indices and in general, is subject to an insidious downward spiral with decreases in quality and quantity of environmental goods and services, which include the resources and benefits obtained from a healthy environment such as clean water, productive soil, healthy forests, etc. The reduction in these services place serious constraints on economic development and human well-being (UNEP 2006).

The African continent is geographically diverse in every sense of the word, Africa's great size and global footprint cause it to experience widely diverse climates, each with different precipitation and temperature patterns, soil regimes, and biomes. Given that many of its climate regions are fragile environments, the challenges to sustaining its burgeoning population are great and often exceed the management capacity of many states in the region.

Africa's human diversity is considerable—the continent is home to 53 sovereign states, 900 million inhabitants, and more than

2,000 languages. The human landscape is complex: there are more than 3,000 discrete tribes and many more ethnic divisions upon which Western colonists imposed their ideologies, resulting in a complicated cultural geography (Price-Smith 2002). This intricate human mosaic influences environmental security because of widely diverse land tenure practices, exploding populations, low education standards, and deficient technical ability (Bennett 1991).

Given our framework for analysis (i.e., Fig. 1), it becomes clear that sub-Saharan Africa is affected by a number of fundamentally destabilizing processes that generate environmentally-triggered instability. Among them are non-sustainable practices, climate change and natural hazards, weak governance, and human activity that have degraded the environment. Africa's complex human and physical geography engender a progression of deleterious outcomes (which are identified by our framework) i.e., significant famine and food security issues, desertification, soil exhaustion, loss of agricultural and ecosystem productivity, pollution, and unchecked migration (Dalby 2002).

The loss of agricultural diversity and food security are two of the critical outcomes identified in our environmental security framework at both local and regional scales. Nearly 70 percent of its people are subsistence farmers and the majority of its states have rural economies. More than 35 percent of the people in sub-Saharan Africa are considered hungry (Sanchez and Swaminathan 2005). The poor and hungry in sub-Saharan Africa are frequently those who live furthest from roads, or belong to tribes and ethnic groups that lack the political and economic wherewithal to assure their food supply (Sanchez and Swaminathan 2005). Overpopulation in sub-Saharan Africa is fundamentally important to food security because growing populations and land tenure customs force people into less productive marginal lands, resulting in short-term production gains; however, these gains are not sustainable in the long term and sometimes accelerate environmental decline (Bennett 1991; Dalby 2002; Diamond 2005). Food security is further influenced by increased pressure to produce cash-crop commercial agriculture, which places increased pressure on already fragile agricultural land. Given its large population and marginal environments, sub-Saharan Africa is exceedingly vulnerable to famine induced by climatic conditions, disease, soil exhaustion, and insufficient water resources, as well as human-induced circumstances abetted by government ineffectiveness, failing distribution infrastructure, civil war, non-sustainable practices, and the absence of human rights (Dalby 2002).

An underlying element to food supply and human survival is access to fresh water (Fig. 3), and stress on this essential resource is expected to intensify in future years (Gleick 2008). Water resources are also a critical component of mining, hydropower generation, tourism, and livestock production, all of which are important to healthy African economies. Paradoxically, segments of sub-Saharan Africa are endowed with substantial fresh water reserves; however in 2005, only about 5 percent of the development potential of clean drinking water was realized resulting from poor infrastructure and a lack of capital to invest in development projects (UNEP 2006). Sub-Saharan Africa's fresh water supply is not evenly distributed and in many places, a moisture deficit exists during more than six months of the year (Love et al. 2006). Consequently, throughout much of sub-Saharan African, fresh water is threatened by overuse, poor management, pollution, and stresses caused by climate variability. Droughts of varying intensity are common in sub-Saharan Africa, and the continent has suffered eight serious droughts since World War II (Zerbe 2004).

Given sub-Saharan Africa's burgeoning population growth, ineffective governance, and complex social fabric, there is a very real probability that these outcomes can trigger, or certainly enable, violent conflict as was seen in Rwanda in 1994 (Diamond 2005). The higher probability for violent conflict is

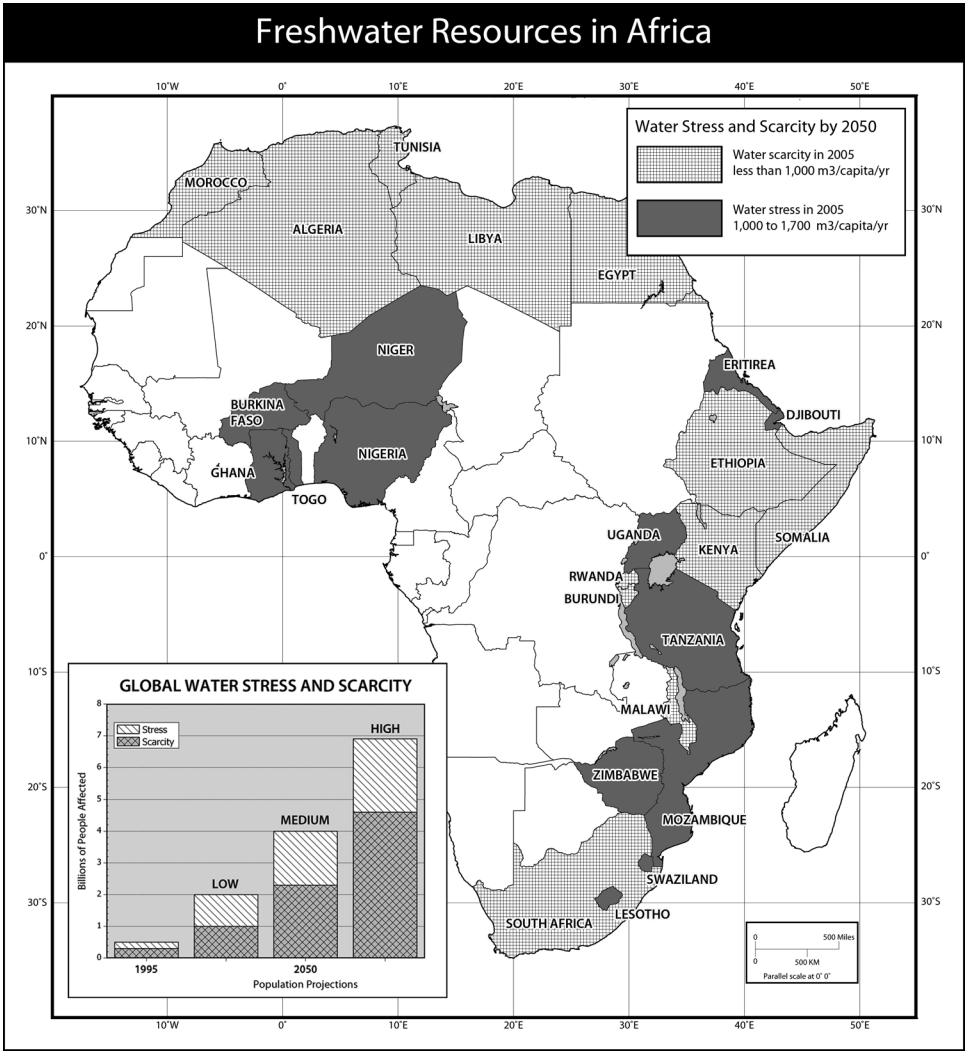

Figure 3. Freshwater Resources in Africa (UNEP 2002).

likely because, unlike many regions in the world, many governments in sub-Saharan Africa are weak and they lack resources or internal governmental structures to ensure stability (Galgano 2007).

CAN ENVIRONMENTAL SECURITY BE MODELED?

After creating an analytical framework, the obvious next question is can modeling key environmental indicators predict potential political instability? There have been several empirical studies investigating how environmental factors influence conflict (for a summary see Thiesen 2008). Miguel et al (2004) showed that economic growth was strongly correlated to civil conflict in Sub-Saharan Africa. Rainfall variation is used as an instrumental variable for economic growth, a technique they argue is ideal for sub-Saharan Africa because only one percent of cropland

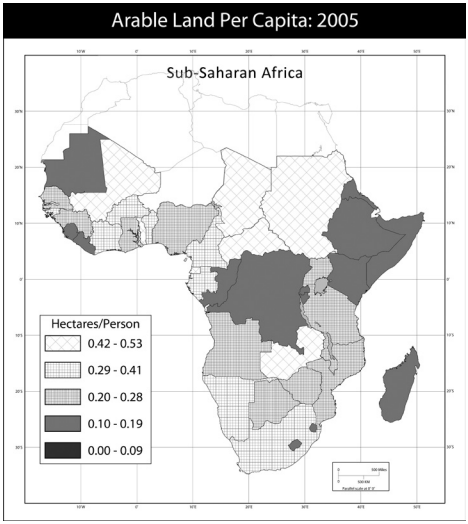

Figure 4. Arable Land *per capita*, 2005. For countries included in the model (Data from FAO, 2009).

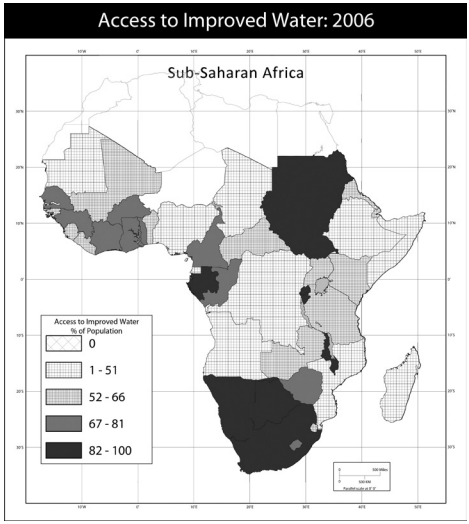

Figure 5. Access to improved water, 2006. For countries included in the model (Data from U.N., 2009).

is irrigated in the median African country. Hendrix and Glaser (2007) found that both long-term and short-term climate trends are correlated with civil conflict in sub-Saharan Africa. Raleigh and Urdal (2007) concluded that environmental variables have only a moderate effect on the risk of civil conflict, whereas freshwater scarcity exerts a stronger influence. They found that high population density is the strongest predictor of armed conflict.

We developed a simple model using two environmental indicators: arable land *per capita* (Fig. 4) and access to improved water (Fig. 5) as independent variables. We chose these indicators because from available data, these best represent the environmental goods and services. Arable land *per capita*, unlike land degradation, which is used in the above mentioned empirical studies, is physiological density. The access to improved water variable, gives us insight into where access is limited. Political stability and non-violence is the dependent variable. Past studies have relied on civil war and armed conflict as a dependent variable. Political instability does not necessarily result in conflict, we use political stability and non-violence as a dependent variable because environmental scarcity can often destabilize governments but does not necessarily result in conflict.

DATA FOR THE MODEL

The states observed in this study and the indicators used were chosen because of data availability. Data for this model were only available at the state level. We acknowledge that arable land *per capita* and access to fresh water can vary greatly within state boundaries, thus the picture is not as precise as we might hope. However, we believe that local environmental degradation (which we do not have data for) can still influence national political stability, which is captured by our dataset. We collected arable land data from the Food and Agriculture Organization (FAO, 2009), and population data from the World Bank (World Bank, 2010). We derived water access data from the U.N. Millennium Development Goal Database (U.N. 2009). The Joint Monitoring Program (2008), which monitors the WHO and UNICEF in water supply and sanitation studies

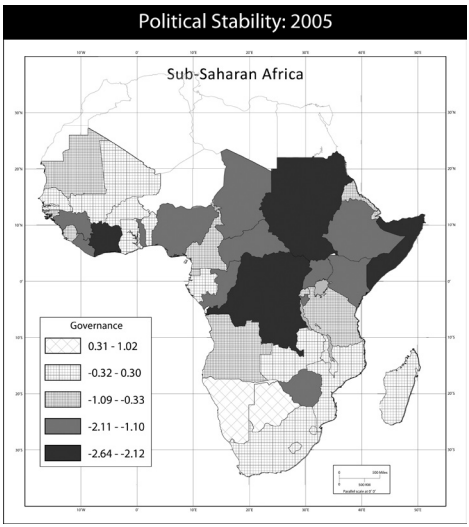

Figure 6. Political Stability, 2005. For countries included in the model (Data from Kaufmann, et al., 2008).

defines an "improved" source as one likely to provide "safe" water (Joint Monitoring Program, 2008). For example, they consider household connections, public standpipes, boreholes, protected wells, protected springs, and collected rainwater to be improved water sources. Access is defined as the availability of 20 liters per person per day from an improved source within one kilometer of a user's dwelling. Improved water access data for states in sub-Saharan Africa range from 20 percent (Ethiopia) to 100 percent (Mauritius).

The dependent variable selected for this analysis is the political stability and non-violence index (Fig. 6) (Kaufmann et al. 2008). This dimension is defined as the likelihood that the government will be destabilized by unconstitutional or violent means (Kaufmann et al. 2008). It measures political stability and non-violence (i.e., PSV) through the survey of households and firms, commercial business information providers, non-governmental organizations, and public sector organizations. The index ranks each state from 1 to 212. After each state is ranked, it is given an indexed score—scores that are more negative indicate more political instability and violence. In 2007, the scores from the political stability and non-violence index ranged from -3.01 (Somalia) to 1.65 (Iceland).

We collected arable land data for 1995, 2000, and 2005. Clean water data were for 1995, 2000, and 2006, and data for political stability and non-violence for 1996, 2000, and 2005. Given the availability of data, the three variables could not be collected for the exact same years. With the collected data we created a cross-sectional data set which includes the variables for each of the time periods mentioned above for 38 sub-Saharan African states.[1]

MODEL SPECIFICATION

To test the relationship between political stability and environmental indicators we used the cross-sectional data set to run the following regression:

$$PSV = \alpha + \beta_1 a_{it} + \beta_1 w_{it} + \beta_1 aw_{it} + \mu_{it}$$

In which PSV is political stability and non-violence, *a* is arable land *per capita*, *w* is percent of population with access to improved water, and *aw* is a multivariable which accounts for the interaction between arable land *per capita* and percent of population with access to improved water. The regression error is represented by μ, regression coefficients are α and β. We do not include a time trend because statistical results including a time trend were statistically insignificant. We ran the model using a fixed effects panel regression, which accounts for the cross sectional nature of the data. The cross-sectional nature of the data is shown by *i*, which represents the 38 states in the study and by *t*, which represents the three time periods included in the study.

RESULTS OF THE ANALYSIS

The results suggest a statistically significant relationship between the environmental indicators used and political stability and

Table 2. Model Results.
All coefficients exceed the $p > 0.05$ threshold.

Variable	Coefficient	T-Stat	Significance
Constant	-3.1436	-6.74	0
Arable land *per capita* (*a*)	4.7224	3.42	0.000846
% Population with access to improved water (*w*)	0.0415	5.02	0.0000019
Multi variable (*aw*)	-0.083	-2.99	0.0033687

non-violence (Table 2). There is a positive correlation between access to improved water and political stability and non-violence also exists. The model suggests that as access to improved water and arable land *per capita* increase, so too does a state's political stability and non-violence rating. Consequently, states with more arable land *per capita* and access to improved water are more likely to be stable. When there are high amounts of arable land *per capita* and access to improved water, the model accurately predicts political stability and non-violence. In 2007, Somalia attained the lowest stability rating and the model shows it as -1.75. It has the lowest access to clean water and only 0.2 hectares/capita of arable land *per capita*. Other states, which are predictably low in resources and stability, include the Democratic Republic of Congo, Nigeria, and Ethiopia. States that are predicted to be more stable according to the model are the relatively stable countries of Botswana, South Africa, and Namibia. One of the drawbacks of using *per capita* data is that the model is not able to detect inequalities within the state, such as the significant tensions in South Africa over land distribution between blacks and whites.

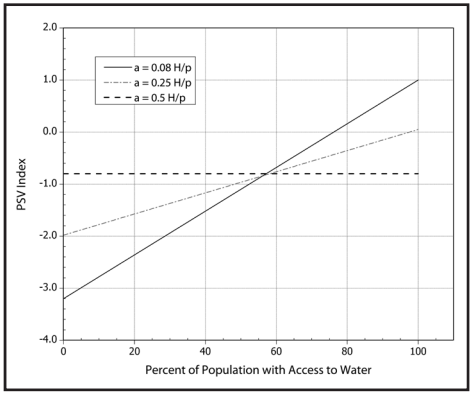

Figure 7. Threshold for Percent of Population: Access to Improved Water (w) The threshold for *w*. This figure shows the change in both Political Stability and Violence (PSV) and percent of population with access to improved water (w) when arable land *per capita* (a) is held constant at 0.08 hectares per person, 0.25 hectares per person, 0.5 hectares per person.

To better understand the regression results, we created two-dimensional graphs that fix one of the independent variable. Fig. 7 demonstrates how the relationship between water (x-axis) and PSV (y-axis) change when arable land *per capita* stays constant. The solid line fixes arable land *per capita* at 0.08 hectares/capita, which is a comparatively low amount of arable land *per capita*. As access to improved water increases, political stability and non-violence also increase. When arable land *per capita* is fixed at 0.25 hectares per person (a median amount), the relationship between water (light dashed line) and government stability still positively correlates, but the slope is less (approximately 0.021). Following this trend, when arable land *per capita* is at 0.5 hectares/capita, the slope decreases to zero and access to improved water no longer has

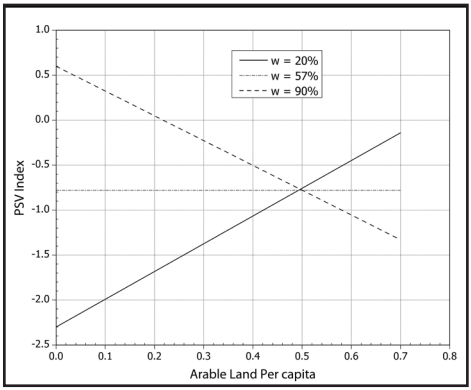

Figure 8. Threshold for Arable Land Per Capita (a) Threshold for *a.* This figure shows the change in both Political Stability and Violence (PSV) and arable land *per capita* (a) when percent of population with access to improved water (w) is held constant at 20%, 57%, and 90%.

any positive correlation to political stability. We assume that this represents the threshold at which access to improved water no longer positively correlates with government stability. This threshold occurs at 0.5 hectares/capita and at -0.8 on the PSV index. In summary, when arable land *per capita* is low, any improvement to access to water will increase political stability and non-violence.

Fig. 8 suggests a similar phenomenon. The solid line fixes access to improved water at twenty percent (the lowest sampling) and shows that the slope is the steepest. As arable land *per capita* increases, there is a clear positive relationship between arable land *per capita* and PSV. When access to improved water rises to 57 percent the slope is zero and there ceases to exist a positive relationship between the two variables. When water is as high as 90 percent, the model is operating in the counterintuitive area. This is an area where resources no longer play a part in contributing to a stabilizing government. The threshold for access to improved water is 57 percent. The threshold for both arable land *per capita* and access to improved water occur at -0.8 on the PSV index.

These thresholds suggest that there is a point at which natural resources no longer influence government stability and other factors probably play a larger role. These other factors might include ethnic conflict, economic shocks, or disease. This model highlights that while environmental factors influence political stability and non-violence, political, economic, and cultural variables are also important, as Thiesen (2008) states "blaming the violence on climate change means overlooking the destructive role of the Sudanese government." The same can be said of Rwanda: the environment contributed to destabilizing the region but ethnic tensions, weak governance, the economic crisis that occurred when the World Bank withdrew economic support, along with the decline in global coffee prices were also significant triggers. In Rwanda, the major environmental limiting factors were arable land *per capita* caused primarily by population growth, soil erosion and exhaustion, and drought conditions. Therefore, we could not state with certitude that our model is an adequate predictor of violence such as that witnessed in Rwanda; and clearly, the literature suggests that the environment seldom is the sole cause of violence, mass migration, and instability. However, our model does suggest that important environmental preconditions existed in Rwanda prior to the 1994 genocide.

So, why are there conflicts in some areas and not others? Our findings indicate that when the political stability and non-violence is below -0.8, our environmental variables play a greater role. Le Billion (2001) suggests, that resource dependency is largely embedded and thus shaped by political economies. If that is the case then stable governments may be better able to navigate around resource shortages and potential conflicts that may result. Many countries that are dependent on environmental resources are able to solve potential conflicts by non-violent means. However countries that are affected by bad governance are deemed prone to 'chaotic' conflicts (Le Billion 2001). Our findings support this, suggesting that states

with a political violence and stability rank of above -0.8 are not as vulnerable to shortages in arable land *per capita* and access to fresh water as states with lower political violence and stability ranks.

SUMMARY AND CONCLUSIONS

Since the early 1990s the precedent for the use of Western and U.N. military assets to address humanitarian dimensions of regional conflict has been now well established; although U.N. and Western leadership has approached these commitments with acute reluctance. Nonetheless, conflicts with an environmental component coupled with divisive ethnic dimensions, such as those observed in Rwanda, have increased pressure on the West and U.N. to commit resources to stability efforts. Experience indicates that the root causes of the conflict are typically poorly understood, which raises the complexity of the problem for government leaders as well as directors of non-governmental organizations and intergovernmental bodies as they attempt to develop relief strategies, especially without an effective framework for understanding the nature of the conflict and its environmental underpinnings. Thus, we feel that our analytical framework and model provides a useful structure by which those leaders may define the natural and human processes, causes, and dimensions of a potential environmental security scenario.

We define environmental security as a process involving environmental risk analysis based on an understanding of the complex interactions between anthropogenic and natural processes that destabilize the environment and contribute to instability or conflict. To operationalize our definition we propose an analytical framework that is not proscriptive or predictive, rather it is a method for organizing the varied, dynamic, and complex environmental factors that produce regional instability and enable violent conflict. The framework is intended to explain links between environmental stress and conflict.

No two conflicts are the same, thus accentuating the need for careful assessments of regional and local conditions to understand how ethnic, economic, and political tensions are affected by environmental stress. The Rwanda case study demonstrates the fundamental problem with this type of analysis: factors of the human landscape and environmental stress are not mutually exclusive. They are complicated and inextricably linked making it difficult to quantify how much the environment has enabled a violent conflict. Nonetheless, the Rwanda example also demonstrates that population growth and severe environmental stress related to non-sustainable practices, superimposed over latent ethic and political divisions will sometimes, in the end, be solved very violently.

The analytical framework is a useful tool for developing a narrative that explains the complex factors that may trigger violent conflict. However, the obvious next question is: can modeling key environmental indicators predict political instability? To answer this question we developed a simple model using two environmental indicators. Our results suggest that a statistically significant relationship exists between the variables—there is a positive correlation between access to improved water and political stability and non-violence. The model suggests that as access to improved water and arable land *per capita* increase, so too does a state's stability. Clearly, there are other factors besides natural resources that play a large part in government stability.

Finally, the model suggests that there is a threshold at which arable land *per capita* and access to improved water predicts stability. When arable land *per capita* is at 0.5 hectares/capita, access to improved water no longer has any positive correlation to political stability. We assume that this represents the threshold at which access to improved water no longer positively correlates with government stability. Similarly, the threshold for access to improved water is 57 percent. The thresholds suggest that there is a point at which natural resources no longer play a

part in a government's stability and other factors – such as ethnic conflict, integration into global markets, or disease – start to play a larger role.

NOTES

1. The 38 sub-Saharan States are: Burundi, Benin, Burkina Faso, Botswana, Central African Republic, Cote d'Ivoire, Cameroon, Republic of Congo, Comoros, Eritrea, Ethiopia, Ghana, Guinea-Bissau, The Gambia, Guinea, Equatorial Guinea, Kenya, Liberia, Lesotho, Madagascar, Mali, Mauritius, Malawi, Namibia, Rwanda, Sudan, Senegal, Sierra Leone, Somalia, Swaziland, Chad, Togo, Tanzania, Uganda, South Africa, Democratic Republic of Congo, Zambia, and Zimbabwe.

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