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CCAPS CLIMATE CHANGE AND AFRICAN POLITICAL STABILITY

Climate Security Vulnerability Model, Version 3.0

Methodology
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The CCAPS Climate Security Vulnerability Model (CSVM) aims to identify places most likely vulnerable to climate security concerns in Africa and go beyond national-level vulnerability rankings to identify vulnerabilities at the subnational level. The model identifies areas of chronic vulnerability relative to the rest of Africa. The maps created by the model are composite representations of climate security vulnerability. Thus, in contrast to maps seeking to chart vulnerability in terms of livelihoods, the CCAPS maps have an explicit security focus, emphasizing situations where large numbers of people could be at risk of death from exposure to climate related hazards.

This document outlines the general mapping process used for the CCAPS vulnerability model, the rationale for inclusion of particular indicators in the model, and the specific process for calculating vulnerability using this model.

THE MAPPING PROCESS

The CCAPS vulnerability model identified four main sources, or "baskets," of vulnerability: (1) *climate related hazard exposure*, (2) *population density*, (3) *household and community resilience*, and (4) *governance and political violence*. Within three of the four baskets, several indicators were identified that contribute to that dimension of vulnerability. Population density is the only basket with a single indicator. All four baskets have equal weight in the final vulnerability analysis.

Because each of the variables in this model was initially measured using different scales, all indicators are first normalized on a scale from 0 to 1, using either percent rank[1] or percentiles.[2] Low scores approaching 0 represent maximum vulnerability and high scores approaching 1 represent the least vulnerability, and thus high overall resilience.

All of the variables within a given basket of vulnerability were then summed and mapped to create composite basket maps for *climate related hazard exposure, household and community resilience, and governance and political violence*. *Population density* was mapped individually and treated as its own basket.

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[1] Percent ranks represent the dispersion between the minimum and maximum. Percent ranks show where a given value is in percentage terms between the minimum and maximum score as represented by the equation percent rank = 1 - (value - min) / (max – min)

[2] Percentiles reflect the percentage of scores below a certain number. The equation representing percentiles is total number of values below X / total number of values.

To form the overall composite, scores for each of the four baskets are then summed together, with each basket receiving equal weight (the research team also experimented with alternative functional forms of the model[3]). To retain the zero to one scale, the data are re-normalized, dividing by the total possible score. These scores then comprise the final composite vulnerability map.

For the 3.0 version of the Climate Security Vulnerability Model, the CCAPS research team created its own shapefile of 692 subnational administrative regions in Africa, typically derived from the latest data source for that country, whether it be the Global Administrative Areas data (GADM), the Global Administrative Unit Layers (GAUL), or Map Library.

SELECTION OF INDICATORS

This section outlines the intuitions behind each basket, followed by a discussion of components in each basket.

Climate Related Hazard Exposure

Geographic location makes some countries more susceptible to climate change impacts. Within countries, some areas, such as the coasts, are more vulnerable to certain kinds of climate related hazards. This study uses historical data of the frequency and magnitude of climate related hazards, including cyclones, wildfires, floods, rainfall anomalies, and chronic water scarcity. The study also includes a measure of low-elevation coastal zones that may be susceptible to future sea level rise and higher storm surges. By including climate related hazard data in this study's vulnerability portrait, the probability of exposure to an event is established as a fundamental part of vulnerability.

Population Density

The model includes population density as one of the four key sources of vulnerability. When natural hazard events occur in densely populated areas, the impact is likely to be more severe than it would be in areas with fewer people. More people will be in need of emergency rations of food and water and medical care, and demands may quickly overwhelm existing facilities and resources. Additionally, if the effects of climate change force rural populations to migrate to urban areas, the sudden population shift may put further strain on local systems.

Household and Community Resilience

The extent to which individuals and communities are affected by natural hazards depends, in part, on their own resources, existing health and nutrition levels, access to health and sanitation services, and levels of education. In the event of a natural hazard event, people and communities that are already sick or under-nourished, that lack access to water and health care, and that have low levels of education are more likely to experience problems than those that are healthy and well-fed, with adequate access to water, health services, and education. Health indicators capture levels of healthiness of the population, with sicker populations more vulnerable to disease, starvation, and thirst as a result of an extreme weather event. Better educated populations are more likely to have information about natural disaster vulnerability, better information about early warnings, and more ability to cope in the event of a disaster through innovation and problem-solving. Health and sanitation service indicators capture availability of community-level resources—such as clean water and medical facilities—that populations use in the event of a weather disaster. This basket thus

[3] For a detailed discussion of the alternative weightings explored, see Joshua W. Busby et al., "Climate Security Vulnerability in Africa Mapping 3.0," presented at the International Studies Association Annual Convention, San Francisco, California, April 2013.

includes indicators grouped into four categories: health of the population, education of the population, access to daily necessities, and access to healthcare services.

Governance and Political Violence

Whether or not individuals experience the worst effects of climate related hazards will partially depend on the quality of governance in the country in which they live. Government support can enable communities to prepare for and adapt to the expected impacts of climate change and can help them respond when climate related disasters do occur. Governments that are either unable or unwilling to look after their citizens can transform a natural phenomenon into a disaster that puts a large number of people at risk of mass death from starvation, disease, or exposure to the elements. In such societies, disorder and instability may also follow natural disaster events. This basket aims to capture this dimension by including a variety of measures, including government responsiveness, government response capacity, openness to external assistance, and political stability. This basket also seeks to capture the degree to which a country has a violent history, which, in certain regions, can complicate the task of providing relief supplies.

CALCULATING VULNERABILITY FOR EACH BASKET

The following section provides a more detailed description of the indicators and vulnerability calculation process used for each basket.

Calculating Climate Related Hazard Exposure

The climate hazard exposure basket includes six indicators representing various climate related hazards:

- cyclone winds
- flood frequency
- wildfire frequency
- rainfall anomalies
- chronic water scarcity
- coastal inundation

In this study, historical, geo-coded climate hazard data on cyclone winds, floods, and wildfires are from UNEP/GRID-Europe. The data on rainfall anomalies and chronic water scarcity are from the Global Precipitation Climatology Centre.

The *cyclone indicator* is an indicator from the UNEP/GRID-Europe platform called “sum of winds.” It is meant to capture both frequency and speed of cyclone events. It is measured in kilometers/year for the period 1970-2009. The resolution of the cyclone wind data is approximately 2 km by 2 km resolution.

The *flood indicator* was derived from a combination of flood observations from 1999 to 2007, the UNEP/GRID-Europe flood dataset, and a GIS model. It is scaled to represent the expected number of events per 100 years. The resolution of the flood data is 1 km by 1 km resolution.

The *wildfire density indicator* represents the expected number of events per year per pixel, or grid cell, from 1995-2011. The resolution of the wildfire data is 1 km by 1 km resolution.

The *rainfall anomalies indicator* is defined as the number of months between 1980-2009 in which the 6-month accumulated rainfall was 1.5 standard deviations or more below the average for that calendar month over the previous 20 years. Using data from the Global Precipitation Climatology Centre (GPCC), researchers calculated

whether or not a given six-month period deviated strongly from the twenty-year average for the same six months. This created a rolling twenty-year average based on the accumulated rainfall for the previous six months. The resolution of the rainfall anomalies data is 0.5°.

The *chronic water scarcity indicator* is based on data from UNEP/GRID-Europe for the period of 1980-2009. It is the monthly coefficient of variation (the standard deviation divided by the mean rainfall). This helps capture chronic water scarcity quite for the following reason. For areas with low mean rainfall values near zero (like deserts), the value for the coefficient of variation will approach infinity. Small deviations in rainfall will generate large changes in the coefficient of variation. The resolution of the chronic water scarcity data is 0.5°.

The *coastal inundation indicator* is included to represent future risk from rising sea levels. CCAPS used a digital elevation model (DEM) to extract the 1-10 meter coastal zone for all of Africa. Data are normalized by percent rank on a zero to 1 scale with areas above 10 meters receive a value of 1 to represent no exposure. The DEM resolution is 30 arc seconds (1 kilometer).

All six indicators were normalized on 0 to 1 scale using percent ranks. Given that both rainfall anomalies and chronic water scarcity indicators were meant to capture similar phenomena related to the effects of changes in rainfall, the model divided the weight between them. Where cyclones, wildfires, floods, and low-elevation coastal zones each represented 20% of the overall climate related hazard basket, that 20% was split equally between rainfall anomalies and chronic water scarcity.

Indicators Used to Assess Physical Exposure to Climate Related Hazards				
Hazard Type (weight)	**Indicator**	**Scale**	**Years of Data Used**	**Source**
Cyclones (20%)	Tropical cyclones average sum of windspeed (km per year)	2 km x 2 km resolution	1970-2009	UNEP/GRID-Europe
Floods (20%)	Floods per 100 years	1 km x 1 km resolution	1999-2007	UNEP/GRID-Europe
Wildfires (20%)	Frequency of wildfires	1 km x 1 km resolution	1995-2011	UNEP/GRID-Europe
Rainfall anomalies (10%)	Number of months between 1980-2009 in which the 6-month accumulated rainfall was 1.5 standard deviations or more below the average for that calendar month over the previous 20 years.	0.5 degree	1980-2009	Global Precipitation Climatology Centre
Chronic water scarcity (10%)	Monthly coefficient of variation	0.5 degree	1980-2009	Global Precipitation Climatology Centre
Coastal inundation (20%)	Low-lying coastal areas within 0 to 10km above sea level	10 m x 10 m resolution		USGS DEM

Calculating Population Density

Using a population density dataset from LandScan at Oak Ridge National Laboratories, the model then mapped population density over initial findings of hazard vulnerability to identify where localities of hazard vulnerability coincide with large population concentrations. The model used a population density

GRID for the year 2011 with a 1-km resolution to account for differences in the number of people likely to be affected by a climate related hazard in a given area. The data were normalized into percentiles on a 0 to 1 scale.

Indicators used to Assess Population Density				
Variable	**Indicator**	**Scale**	**Years of Data Used**	**Source**
Population Density	Ambient population (average over 24 hours)	Subnational at 1 km x 1 km resolution	2011	LandScan Oak Ridge National Laboratory

Calculating Household and Community Resilience

This basket measures the ability of households and communities to fulfill their own immediate needs during and after exposure to climate hazards. Low levels of such capacity reflect high levels of household- or community-level vulnerability. Four different but related characteristics represent this capacity: (1) health of the population, (2) education of the population, (3) access to daily necessities, and (4) access to healthcare services.

CCAPS assessed a range of indicators to represent these four characteristics based on an extensive review of prior literature and an assessment of empirical evidence for the statistical significance of these indicators. The model uses the latest data point for each series, presuming this to be the best proxy of the current situation in the given country. The study sought to use subnational data for the indicators where it was available.

This selection process left eight indicators—two in each category:

- Adult literacy rate
- Primary school enrollment
- Infant mortality rate
- Life expectancy at birth
- Percentage of population with access to improved drinking water sources
- Percentage of children underweight
- Health care expenditures per capita
- Percentage of births in a healthcare facility

The subnational indicator for *adult literacy rate* was derived using subnational data from USAID Demographic and Health Surveys (DHS), UNICEF Multiple Indicator Cluster Surveys (MICS), and Stats SA and national data from the World Bank's World Development Indicators (WDI).

The subnational indicator for *primary school enrollment* was derived using subnational data from DHS, MICS, and StatsSA and national data from UNICEF.

The subnational indicator for *infant mortality rate* for 2008 was derived by the Center for International Earth Science Information Network (CIESIN) at Columbia University using survey data from DHS, UNDP National Human Development Reports, UNICEF statistics, and in some cases national survey data.

The indicator for *life expectancy at birth* is national-level data from WDI.

The subnational indicator for *percentage of children underweight* was derived using subnational data from DHS and national data from WDI.

The subnational indicator for *access to improved drinking water source* was derived by CCAPS using subnational data from DHS, MICS, Stats SA, and national data from WDI. These subnational surveys ask similar questions about a household's main source of drinking water.

The indicator for *health care expenditures per capita* is national-level data from WDI.

The subnational indicator for *delivery in a healthcare facility* is derived using subnational data from DHS and UNICEF and national data from UNICEF.

In total, six of the eight indicators in this basket have subnational coverage. All of these data sources were converted into percent ranks and normalized on a 0 to 1 scale. Each of the four categories included two indicators, and each category received an equal weight in the index of 25%. Each indicator in the category would thus receive 12.5% of the weight of the whole basket. In the event that a particular indicator was missing data, the other indicator would take on the full 25% weight of that category.

Indicators Used to Assess Household and Community Resilience				
Category (weight)	**Indicator**	**Scale**	**Years of Data Used**	**Source**
Education (25%)	Literacy rate, adult total (% of people ages 15 and above)	National, CCAPS First Administrative District	DHS 2003-2011, Stats SA 2011, World Development Indicators (WDI) 2006-2010	Subnational data from DHS, MICS, Stats SA; National data from WDI
	School enrollment, primary (% gross)	National, CCAPS First Administrative District	DHS 2003-2011, Stats SA 2011, MICS 2006-2010, UNICEF 2003-2008	Subnational data from DHS, MICS, Stats SA; National data UNICEF
Health (25%)	Infant mortality rate adjusted to national 2000 UNICEF rate	CCAPS First Administrative District	2008	Environmental Indications and Warnings Project
	Life expectancy at birth (years) both sexes	National	2008, 2010, 2011	WDI
Daily Necessities (25%)	Percentage of children underweight (more than two standard deviations below the mean weight-for-age score of the NCHS/CDC/WHO international reference population	National, CCAPS First Administrative District	DHS 1999-2010, WDI 2000, 2004-2008, 2011	Subnational data from DHS; National data from WDI
	Population with sustainable access to improved drinking water sources total (%)	National, CCAPS First Administrative District	DHS 2003, 2005-2011, MICS 2006-2007, 2010, Stats SA 2011, WDI 2001, 2006, 2008-2010	Subnational data from DHS, MICS, Stats SA; National data from WDI

Access to Healthcare (25%)	Health expenditure per capita (current US$)	National	WDI 2001, 2010	WDI
	Delivery in a healthcare facility (% of births)	National, CCAPS First Administrative District	DHS 1999-2008, 2010, UNICEF 2003-2008	Subnational data from DHS, UNICEF; National data from UNICEF

Calculating Governance Vulnerability and Political Violence

This basket measures the potential effectiveness of any governmental response during and after exposure to climate hazards, and thus whether an extreme weather event has more potential to become a disaster. Five variables comprise this basket: (1) government responsiveness, (2) government response capacity, (3) openness to external assistance, (4) political stability, and (5) presence of political violence. The model used national-level indicators for the first four variables to develop a national composite score for each variable. The model combined these scores with subnational data on political violence to create a composite score for this basket.

First, *voice and accountability* from the World Bank measures how responsive a government is to the needs of its citizens. Although not exactly bounded, measurements range from roughly of -2.5 to +2.5 with zero representing the approximate median. The CCAPS model uses a diminishing weighted average of the 2011, 2010, 2009, and 2008 scores, giving 40% of the weight to the most recent 2011 data, 30% to 2010, 20% to 2009, and 10% to 2008. The rationale for unequal weighting was to ensure that the single year did not just reflect an anomalous year and to give some weight to trends in governance, either for better or worse.

Second, *government effectiveness* from the World Bank captures the ability of a government to implement policy in general and, in particular, to undertake post-disaster relief operations. It is measured on the same scale as *voice and accountability.*

Third, the *KOF Index of Globalization* serves as a proxy for a country's level of global integration. It uses data on three dimensions of globalization—economic, social, and political—to create an overall globalization score between zero and 100 that measures a country's level of integration in the global system. A country with a higher degree of global integration will be better positioned to obtain disaster assistance from the international community. Autarkic or less well-integrated countries may be less able or willing to receive outside assistance in the event of extreme weather events. Such assistance could take the form of aid from bilateral or multilateral donors or international humanitarian organizations, or it could be in the form of remittances from overseas family or diasporas of the affected population.

Fourth, two metrics for *political stability* are included, as less stable governments—whether democratic or autocratic—are more easily upset by the shock of a disaster or the unrest of a stressed population. CCAPS developed these two metrics using data from the Polity IV Project. First, CCAPS created a measure we call *polity variance.* The Polity IV Project reports a polity score for most countries in the world on a scale of -10, the most autocratic, to +10, the most democratic. Without preference for democracy or autocracy, this study used the difference between a country's highest and lowest polity scores in the past ten years as a measure for how much a country's government has changed. A zero indicates that the government has experienced no change, while a higher score indicates that the government has changed considerably. For the second metric of political stability, CCAPS used a count of the total *number of stable years* since a country has undergone a major regime change, defined by the Polity IV Project as a change of three points or more in three years. In this case, a higher year count indicates a more stable government. When generating the percent ranks, the study gave each of these two metrics equal weight within the *political stability* variable.

Lastly, a measure of *political violence* is included, as this is thought to severely limit a government's ability to deliver emergency relief, or if the government itself is responsible for the violence, indicate a lack of willingness to provide humanitarian relief after climate related emergencies. Unlike the other indicators in the governance basket that use national-level data, political violence is assessed at a subnational level using GIS. The study spatially joined geo-referenced data on battles and violence against civilians from the Armed Conflict Location and Event Dataset (ACLED) to the CCAPS level one administrative unit and calculated the total number of events within each administrative area.

All of these data sources were converted into percent ranks and normalized on a 0 to 1 scale. Each of the five variables received an equal weight in the index of 20%.

Indicators used to Assess Governance and Political Violence				
Category (weight)	**Indicator**	**Scale**	**Years of Data Used**	**Source**
Government Responsiveness (20%)	Voice and Accountability	National	2008, 2009, 2010, 2011	WDI
Government Response Capacity (20%)	Government Effectiveness	National	2008, 2009, 2010, 2011	WDI
Openness to External Assistance (20%)	Globalization Index	National	2009	KOF Index of Globalization
Political Stability (20%)	Polity Variance	National	2002-2011	Polity IV Project
	Number of Stable Years (as of 2011)	National	1855-2011	Polity IV Project
Political Violence (20%)	Battles and Violence Against Civilians	CCAPS First Administrative Division	1997-2012	Armed Conflict Location and Events Database (ACLED)

CALCULATING COMPOSITE VULNERABILITY

The climate security vulnerability model combines the indicators for all four baskets of vulnerability—climate related hazard exposure, population density, household and community resilience, and governance and political violence—to develop a composite map of vulnerability.

Composite scores for each of the four baskets are summed together, with each receiving equal weight. To retain the zero to one scale, the data are re-normalized, dividing by the total possible score. Low scores approaching zero represent maximum vulnerability and high scores approaching 1 represent the least vulnerability, and thus high overall resilience. These scores then comprise the final composite vulnerability map.