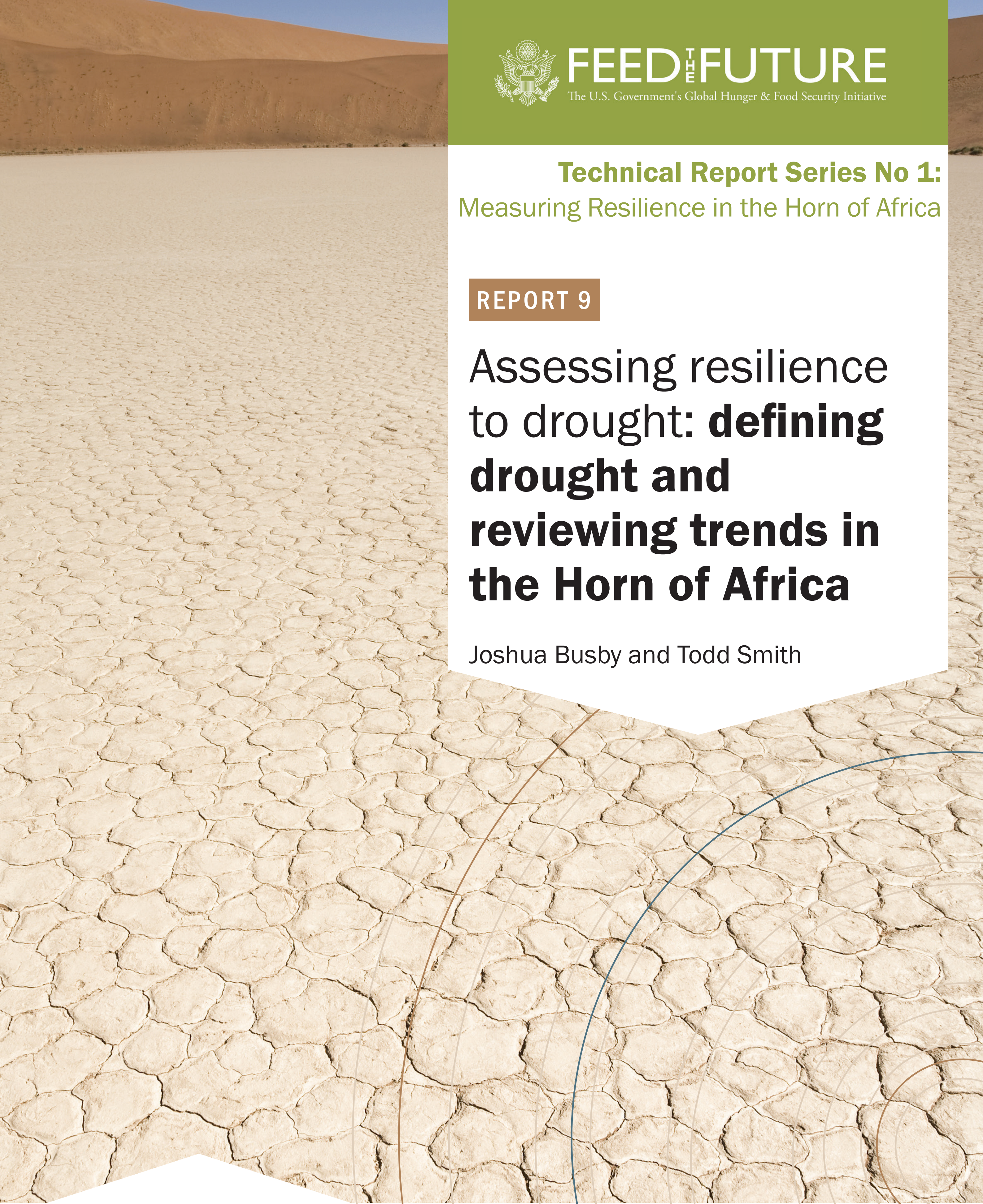

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Technical Report Series No 1:
Measuring Resilience in the Horn of Africa

REPORT 9

Assessing resilience to drought: **defining drought and reviewing trends in the Horn of Africa**

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1

Background to the drought in the Horn of Africa

In 2011 and extending to 2012, the East Africa region and, in particular, the Horn of Africa experienced the worst drought in 60 years, causing severe food shortages and livestock losses at an unprecedented scale and leaving 9.5 million people in need of assistance in Somalia, Djibouti and Ethiopia[1]. It is worth noting, however, that significant variation in rainfall in this part of the world can be traced back to at least the 13th century. Data indicate that over the past millennium, "equatorial east Africa has alternated between contrasting climate conditions, with significantly drier climate than today during the period of AD 1000-1270, and a relatively wet climate from 1270-1850, which was interrupted by three prolonged dry episodes".[2]

What has happened over the past century, and most significantly over the last 30 years, is that droughts have become more frequent and more severe, affecting an ever-increasing population. The drought cycle has become shorter due to a variety of reasons, climate change and environmental degradation being cited as but two of them, but the net result of this increase in frequency has been a reduction in the time a population has to recover from the previous drought and prepare for the next. It is this "resilience", or the capacity that ensures stressors and shocks do not have long-lasting adverse development consequences and enables support to trajectories enhancing growth and prosperity[3], which governments in the IGAD region are seeking to enhance.

[1] http://www.thejournal.ie/un-somalian-famine-is-over-but-action-still-needed-347449-Feb2012/

[2] Verschuren, D., Laird, K.R. and Cumming, B.F. 2000. Rainfall and drought in equatorial east Africa during the last 1,100 years. *Nature* 403, pp 410-414.

[3] Definition adopted by the Technical Consortium (technicalconsortium.org), derived from that adopted by the Resilience Measurement Technical Working Group and others.

Defining drought

2

As a focus area of the Technical Consortium is to assess the resilience of populations to drought, one has to have a clear definition of "drought." Climatologists identify three different types of drought: (1) meteorological drought, (2) hydrological drought and (3) agricultural drought (a fourth category of socio-economic drought is sometimes distinguished, but not relevant to this paper).

The US National Oceanic and Atmospheric Administration (NOAA) provides succinct descriptions of each of these. Meteorological drought is usually defined as below normal expected rainfall over a defined period based on long-term observed averages. This is the easiest to observe and is, at least in the short-term, wholly exogenous to human systems. According to the NOAA National Weather Service[4], hydrological drought usually occurs following periods of extended precipitation shortfalls that impact water supply (i.e. streamflow, reservoir and lake levels, ground water), potentially resulting in significant societal impacts. Because regions are interconnected by hydrologic systems, the impact of meteorological drought may extend well beyond the borders of the precipitation-deficient area. Agricultural drought links various characteristics of meteorological (or hydrological) drought to agricultural impacts, focusing on precipitation shortages, soil water deficits, reduced ground water or reservoir levels needed for irrigation, and so forth[4].

Most of the datasets and scholarship on Africa focus on rainfall, since irrigation is very limited and most farmers rely on rain-fed agriculture. How one operationalizes the definition of drought can have major effects on the findings for what areas are found to have historically been drought-prone in the past. Many use variations of the Standardized Precipitation Index, although it is unclear how well this captures common conceptions of drought in Africa. The specific operationalization of drought very much depends on the reference period for normal rainfall, the length of the period one is studying to assess deviations from normal rainfall, whether one is using satellite data or rain gauge data, etc.[5].

For pastoralists and other communities that rely on groundwater wells for livestock, other metrics of water availability might be important. At the same time, when people reference "drought" in this part of the world, they may also be conflating some measure of negative rainfall anomalies with chronic water scarcity in arid lands, which is a wholly different concept than drought. If, for example, drought is defined as below normal rainfall, it becomes meaningless to discuss drought in areas with very little "normal" rainfall based on long-term averages.

To address these challenges of defining drought, the approach discussed in this paper incorporated two measures to account for both rainfall anomalies and chronic water scarcity.

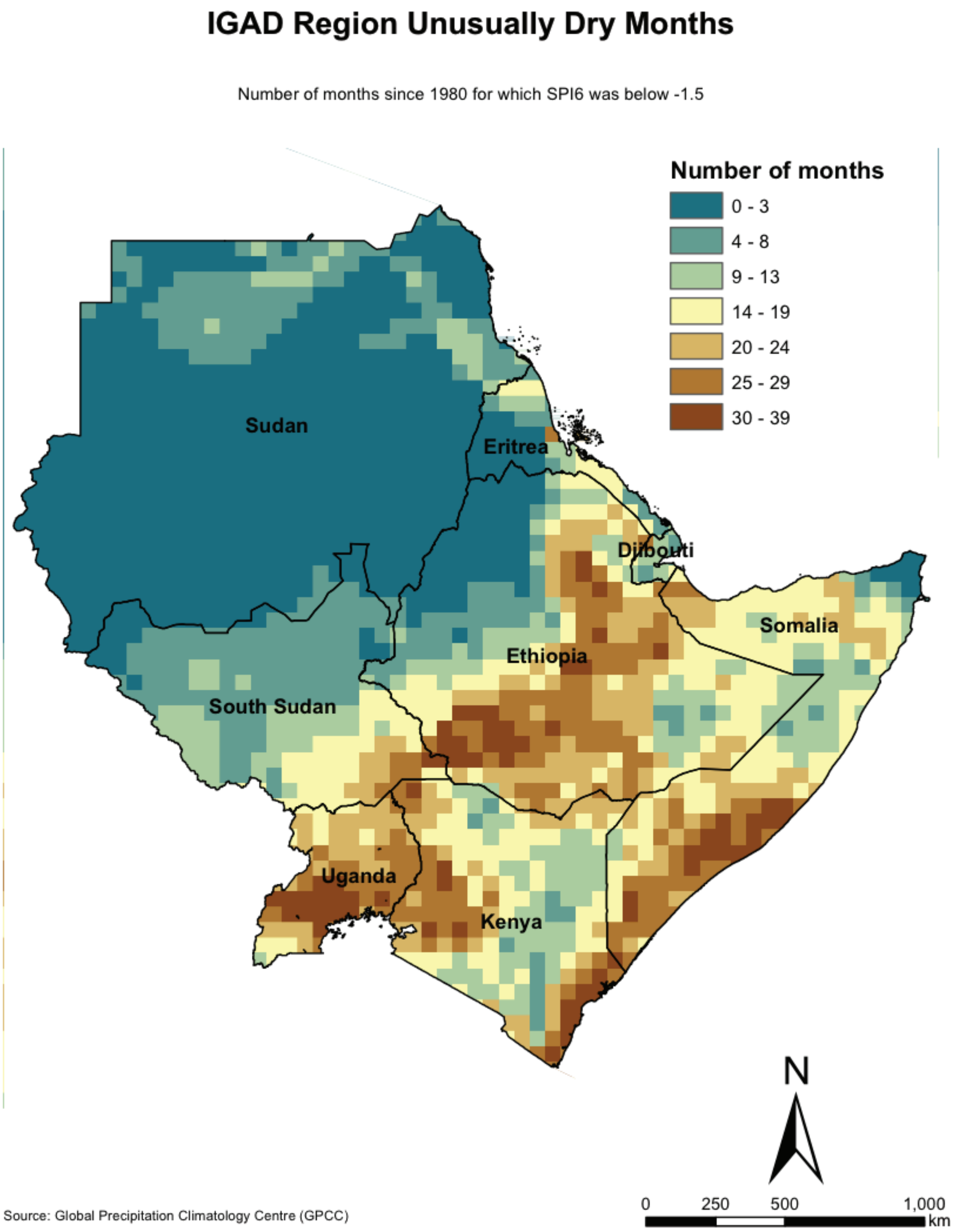
[4] NOAA National Weather Service. 2008. *Drought: Public Fact Sheet.* http://www.nws.noaa.gov/os/brochures/climate/DroughtPublic2.pdf.

[5] Lyon, B. 2011. *Quantifying Drought – Some Basic Concepts. Memo for Workshop on Mapping and Modeling Climate Security Vulnerability.* LBJ School of Public Affairs. http://strausscenter.org/images/pdf/climateworkshop/lyon_memo_for_web.pdf.

In terms of rainfall anomalies, it is presumed that people, particularly farmers, will have some appreciation of what the rainfall should look like over a given period (in the operationalization, the previous six months). The memories of adults may stretch back about twenty years. Thus, if the accumulated rainfall deviates strongly from the previous patterns over the last twenty years, this could have a major impact on the ability of farmers and other water users to plan, plant, and execute their operations, with knock-on disruptive consequences. Using data from the Global Precipitation Climatology Centre (GPCC), it was therefore calculated whether or not a given six-month period deviated strongly from the twenty-year average for the same six months. This allowed the generation of a rolling six-month standardized precipitation measure for the period 1980-2009.[6]

[6] This 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. The drought data are represented by a raster with values based on the six-month standardized precipitation index (SPI) according to the severity of drought in a given calendar year. If the SPI does not drop below -1 for at least three consecutive months, the value is set to zero. If the six-month SPI does drop below -1 for at least three consecutive months, the value is set to 1; if it is below -1.5 for at least two consecutive months, the value is set to 1.5. If both criteria are met, the value is set to 2.5.

Figure 1: Map of IGAD region detailing unusually dry months



The static map in Figure 1 is somewhat misleading as not all months and not all years are necessarily ones of negative water anomalies. To get at the variation over time, Figure 2 on the following page illustrates the rainfall deviations for the period 1990 through the end of 2009.

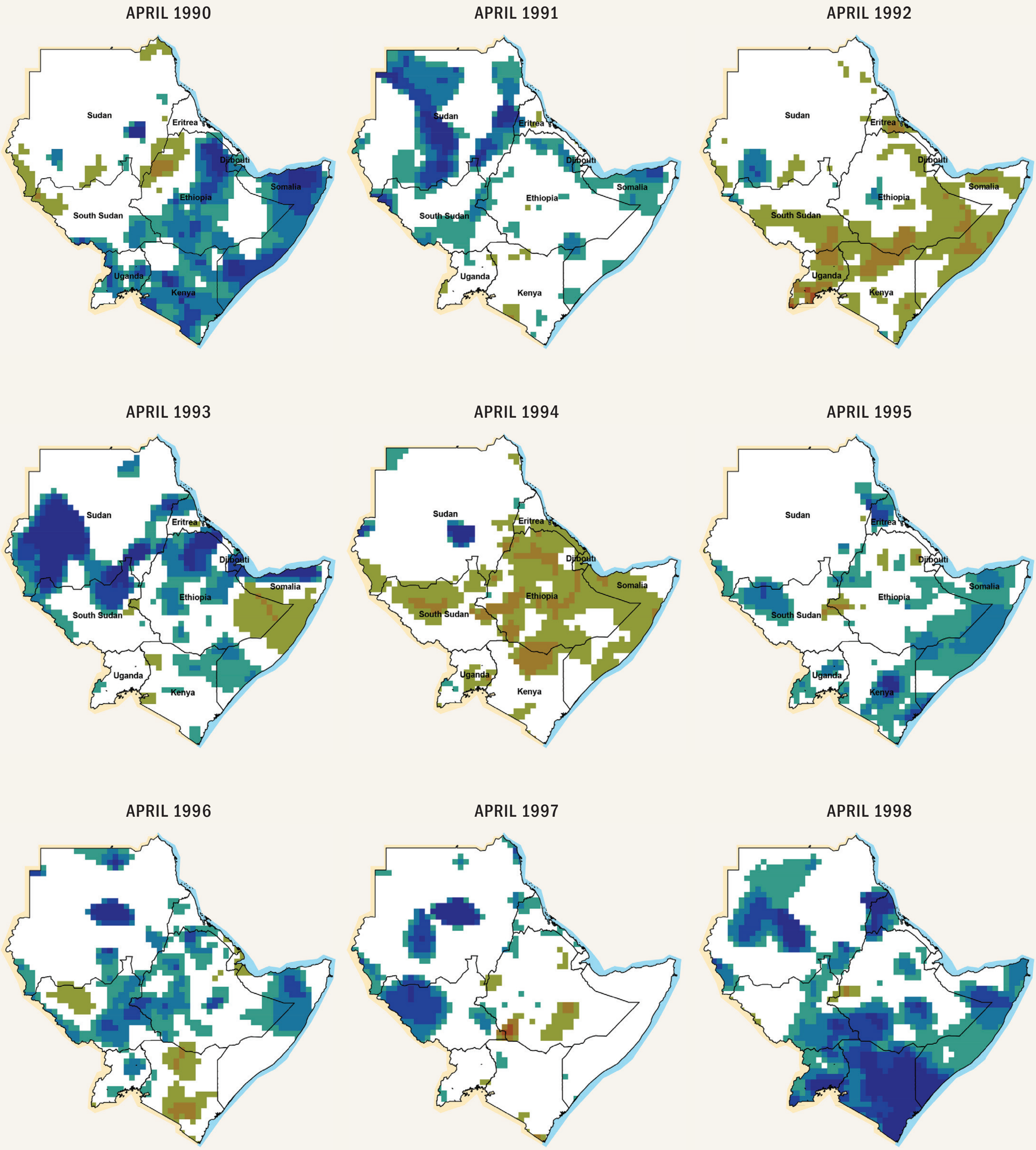
SUMMARY OUTCOME:
Looking at this data, central eastern Ethiopia, much of Uganda (but especially the west), eastern Kenya, and southern Somalia have all experienced many months of unusually dry months since 1980.

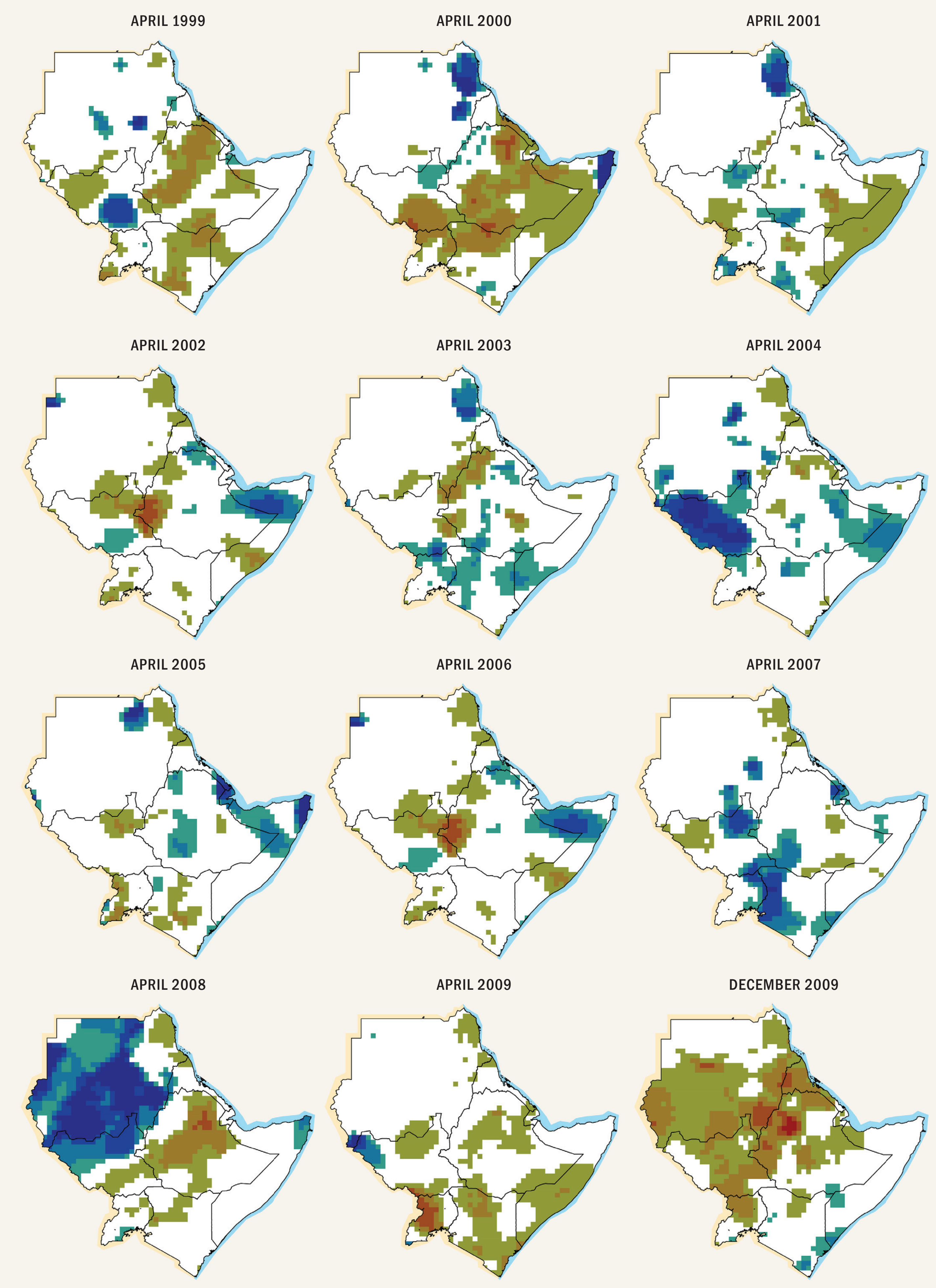
Figure 2: Rainfall deviations from April 1990 - December 2009 for the IGAD Region, using a 6-month Standardized Precipitation Index

Source: Global Precipitation Climatology Centre (GPCC)

KEY:

3.00 and above (exceptionally wet)	0.75 to 1.24 (moderately wet)	-1.99 to -1.25 (very dry)
2.00 to 2.99 (extremely wet)	-0.74 to 0.74 (near normal)	-2.99 to 2.00 (extremely dry)
1.25 to 1.99 (very wet)	-1.24 to -0.75 (moderately dry)	-3.00 and below (exceptionally dry)

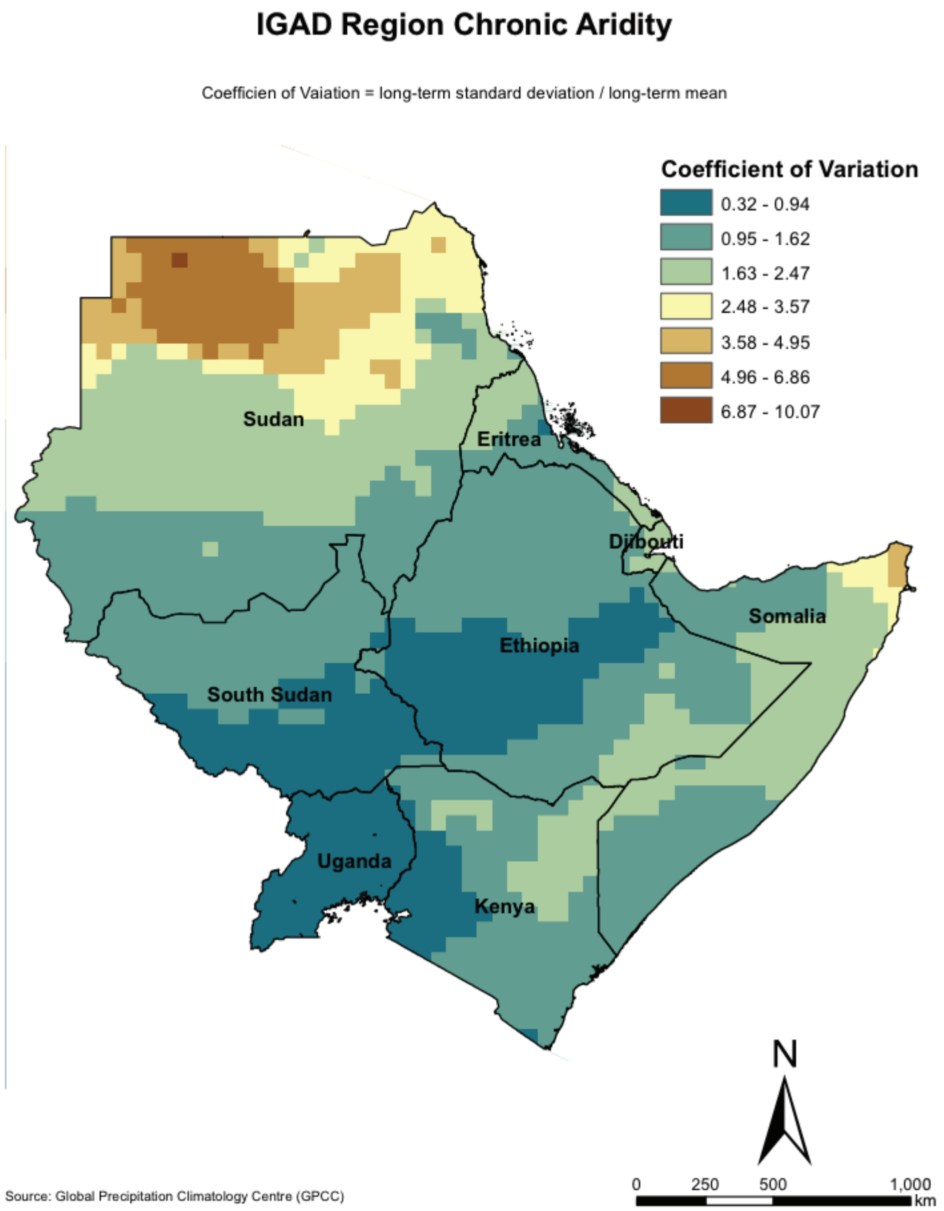



APRIL 1999
APRIL 2000
APRIL 2001
APRIL 2002
APRIL 2003
APRIL 2004
APRIL 2005
APRIL 2006
APRIL 2007
APRIL 2008
APRIL 2009
DECEMBER 2009

[7] The coefficient of variation is simply the standard deviation divided by the mean rainfall. This addition was motivated by our fieldwork where respondents noted that our maps failed to capture areas of chronic water scarcity, already at risk to water shortages and likely to fare worse with climate change. 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.

To get at places with chronic water scarcity such as areas of northern Kenya, the average monthly coefficient of variation was calculated.[7] Again, the GPCC data was used, which allowed the data to be updated for the period 1980-2009. For both of these indicators, values across the entire continent could be generated.

Figure 3: Map of IGAD region detailing chronic aridity



SUMMARY OUTCOME:
Northern Sudan and Puntland in Somalia are the areas that have the largest coefficients of variation and reflect areas with greater water scarcity. Pastoral areas in north eastern Kenya and southern Ethiopia also have relatively high chronic water scarcity.

Climatic projections

3

While the historic data of rainfall anomalies and chronic water scarcity from GPCC are useful, climate change is expected to alter the future distribution of rainfall in the region. For that reason, a collaboration with climate modelers, Kerry Cook and Edward Vizy, from the University of Texas was initiated to both simulate the present day climate and generate projections of future climate in Africa for the mid 21st century.

Appendix A is an extract from the joint piece in Climatic Change describing the model[8].

One of the indicators that they created for the joint modeling work was an indicator of the number of dry days, for which they simulated the contemporary period roughly 1980-2000 as well as the mid-century projection. This allows for the evaluation of areas that will be come even drier as a result of climate change.

The number of dry days was defined in the study as the number of days per year when the daily rainfall rate is less than 1 mm for at least 21 consecutive days, is used to approximate drought.

The map in Figure 4 (see page 12) depicts the late 20th century simulation for the entire continent, with unpopulated areas excluded. One can see that far eastern Ethiopia and northern Kenya experienced dry days for most of the year. Northern Ethiopia near Djibouti and Eritrea, pockets in Somalia, and central Sudan near the Sahel were very dry as well.

The map in Figure 5 (see page 13) shows the 2050 projection, and Figure 6 (see page 14) evaluates the change between the present-day simulation and the projection. Most notable is that eastern Ethiopia and southern Sudan are projected to be a little wetter in the 2050 projection. Western Ethiopia and south-eastern Kenya are the areas projected to experience the largest increase in number of dry days.

In other work, they have extended the number of mid-century simulations and have modeled changes in the growing season.[9]

[8] Busby, J., Cook, K., Vizy, E., Smith, T. and Bekalo M. 2014. Identifying Hot Spots of Security Vulnerability Associated with Climate Change in Africa. *Climatic Change* 124 (4): 717–31.

[9] Cook, K.H. and Vizy, E.K. 2012. Impact of Climate Change on Mid-Twenty-First Century Growing Seasons in Africa. *Climate Dynamics* 39 (12): 2937–55.

Figure 4: Map of Africa showing number of dry days per year in populated areas in the late 20th century

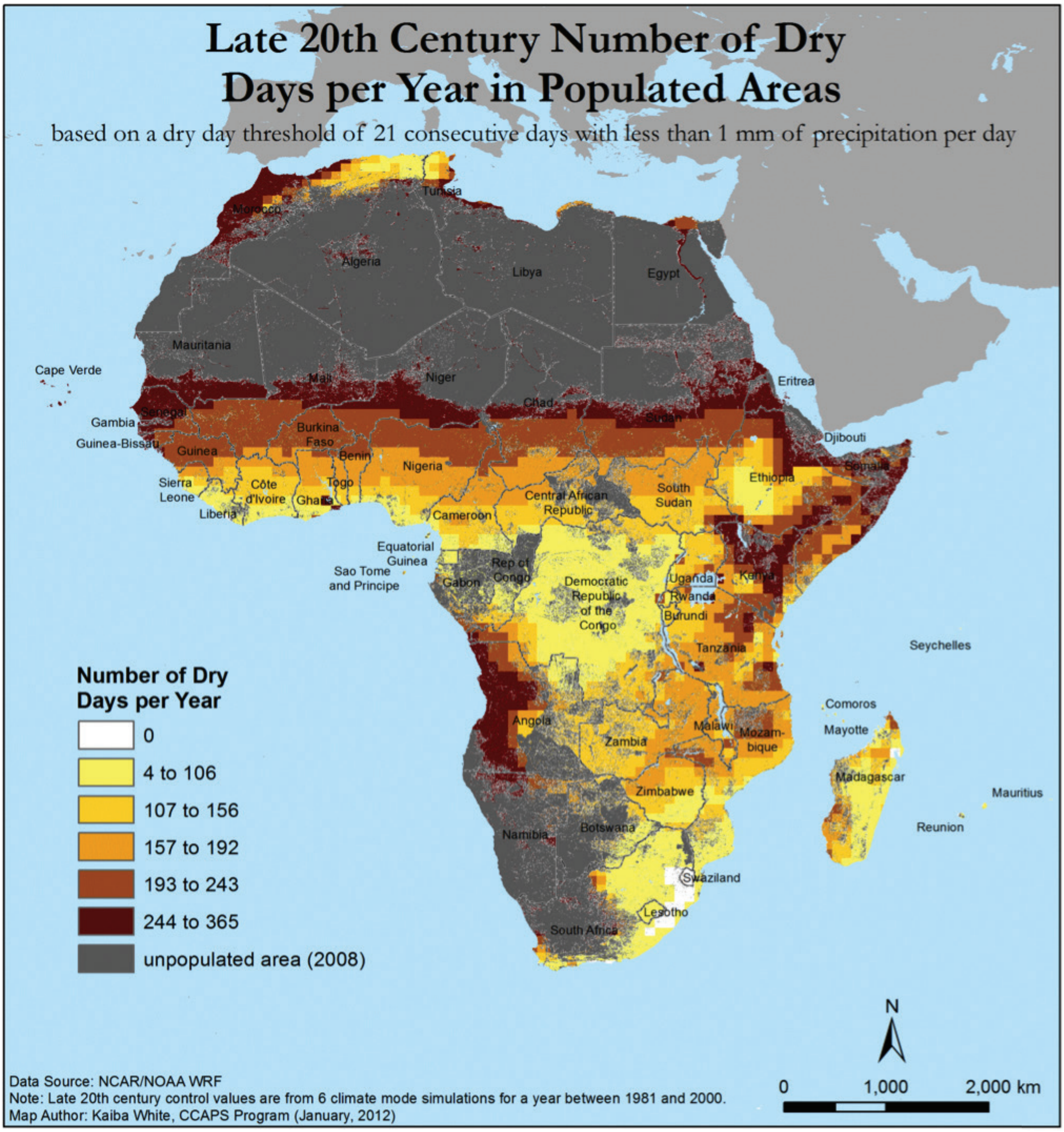


Figure 5: Map of Africa showing number of dry days per year in populated areas in the mid-21st century

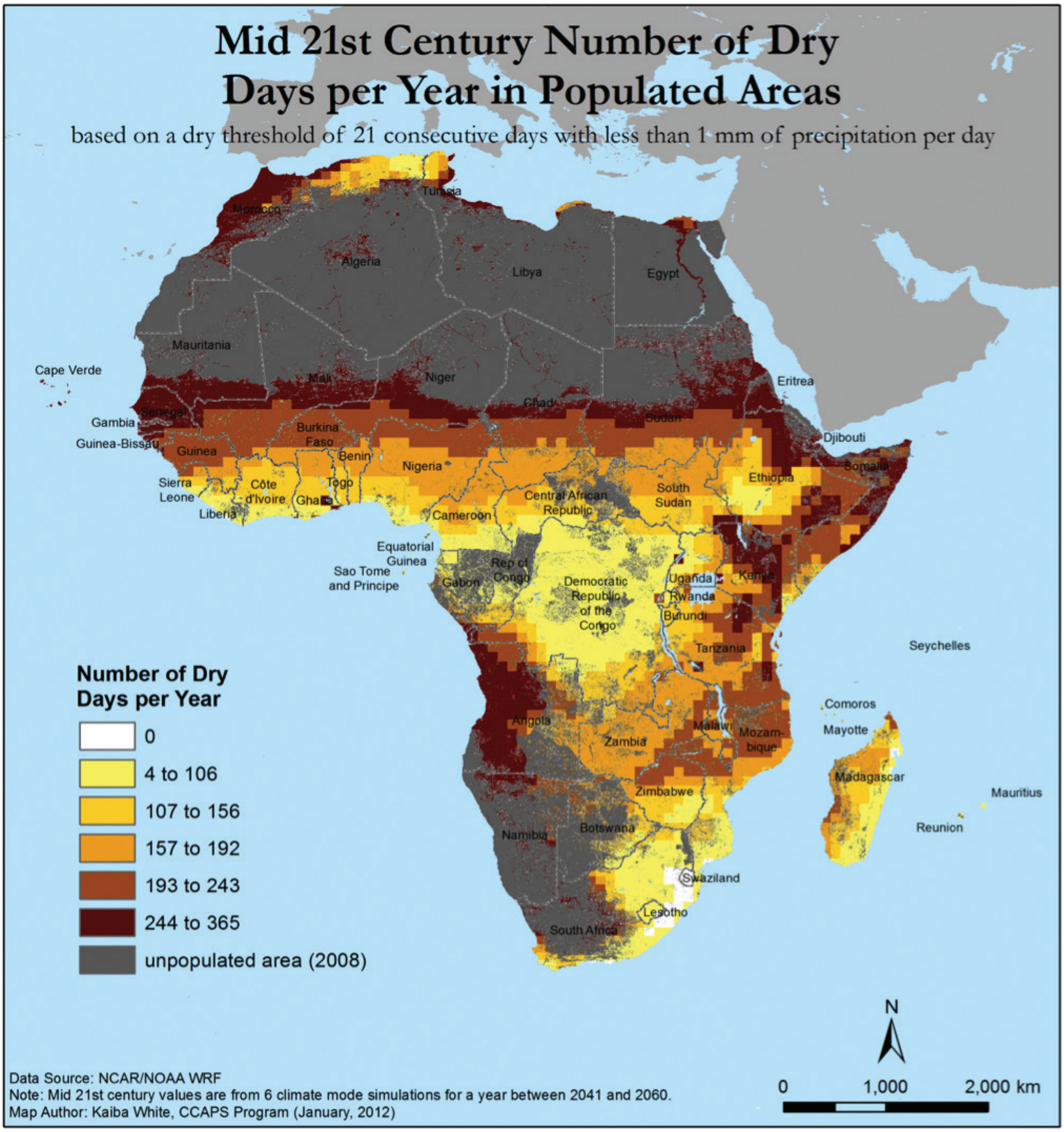
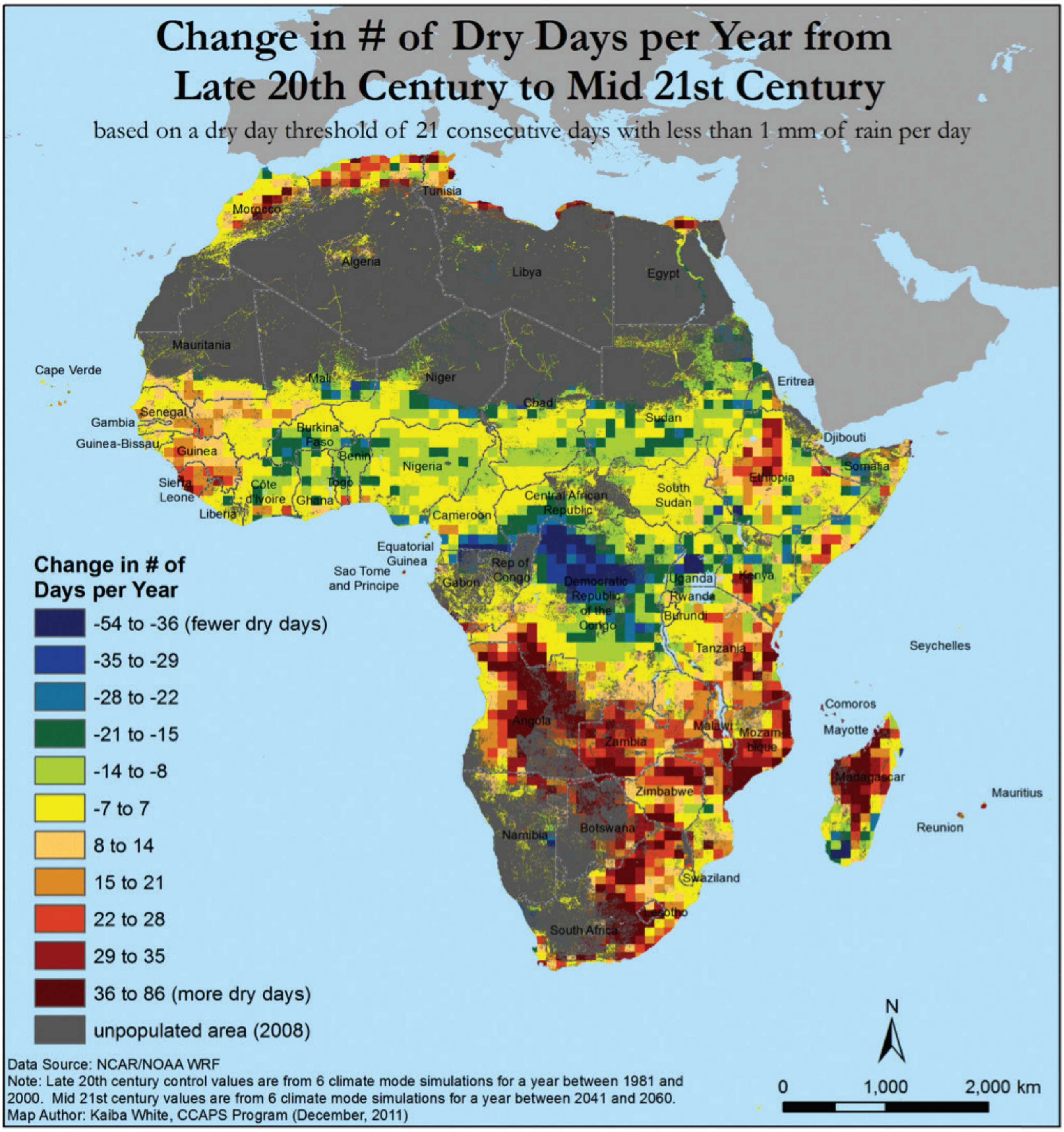


Figure 6: Map of Africa showing the change in the number of dry days per year in populated areas from the late 20th century to mid-21st century



Appendix A

The climate change projections used in this study result from the integrated application of AOGCMs and a RCM. The RCM used is the National Center for Atmospheric Research/ National Oceanic and Atmospheric Administration (NCAR/ NOAA) Weather Research and Forecasting[10] regional model. Future lateral and surface boundary conditions for the regional model are derived from simulations using AOGCMS[11] that were run in support of the Intergovernmental Panel on Climate Change's (IPCC) Fourth and Fifth Assessment reports (AR4 and AR5, respectively). While the horizontal space scales of AOGCMs, generally about 150 to 200km, are not ideally suited to evaluate regional changes in extreme weather events[12], they provide information about large-scale changes in the atmosphere and ocean that are needed for constraining the regional model simulation. In addition to providing finer resolution than the AOGCMs, regional modeling allows one to select model physical parameterizations that work well in the region of interest, in this case over Africa.

An ensemble regional modeling approach is used to improve the reliability of the simulations and provide a tool for evaluating confidence. Two ensembles, each consisting of 6 year-long climate-mode ensemble members[13], are constructed and run using a 90-km domain that extends from 61°W - 101°E and from 52°S - 60°N. The first ensemble represents the late 20th century (1981-2000). Initial, surface and lateral boundary conditions are derived from the 1981-2000 monthly climatology of the National Centers for Environmental Prediction reanalysis 2, [14] linearly interpolated to form the 6-hourly conditions needed as described in Cook and Vizy (2012). Each ensemble member differs only in their initial conditions.

The second ensemble represents the mid-21th century (2041-2060) under the IPCC AR4 mid-line A1B emissions scenario. CO_2 concentrations are adjusted from late 20th century values to 536 ppmv, which represents the 2041-2060 average under the A1B emissions scenario. Initial and lateral boundary conditions are derived by taking AOGCM anomalies, calculated as the differences between monthly-mean, A1B-forced simulations averaged over 2041-2060 and monthly-mean historical simulations averaged over 1981-2000, adding them to the NCEP2 reanalysis climatological monthly values, and linearly interpolated to form the 6-hourly values needed.

[10] Skamarock, W.C., Klemp, J.B., Agard, J. Gill, D.O., Barker, D.M., Wang, W. and Powers, J.G.. 2005. *A Description of the Advanced Research WRF Version 2*. Boulder, CO: NCAR/ TN-408+STR. http://www.mmm.ucar.edu/wrf/users/docs/arw_v2.pdf.

[11] The 9 AOGCMs used are CGCM3.1, CNRM-CM3, ECHAM/MPI-OM, GFDL-CM2.0, MIROC3.2 (medres), MRI-CGCM3.2, NCAR CCSM3, NCAR PCM, UKMO-HadCM3. The process is detailed in (Cook and Vizy 2012).

[12] Crétat, J., Vizy, E.K. and Cook, K.H.. 2013."How Well Are Daily Intense Rainfall Events Captured by Current Climate Models over Africa? *Climate Dynamics*, 1–21.

[13] Climate-mode boundary conditions include seasonality, but filter out shorter timescales. This process has been shown to be an effective approach to understand climate variability over Africa in other studies (e.g., Vizy and Cook 2002; Patricola and Cook 2007, 2010). A detailed description on the climate-mode ensemble design methodology is provided in Cook and Vizy (2012).

[14] Kanamitsu, M., Ebisuzaki, W., Woollen, J., Yang, S-K., Hnilo, J.J., Fiorino, M. and Potter, G. L. 2002: NCEP–DOE AMIP-II Reanalysis (R-2). *Bull. Amer. Meteor. Soc.*, 83, 1631–1643.

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