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Climate change, rainfall, and social conflict in Africa

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Abstract

Much of the debate over the security implications of climate change revolves around whether changing weather patterns will lead to future conflict. This article addresses whether deviations from normal rainfall patterns affect the propensity for individuals and groups to engage in disruptive activities such as demonstrations, riots, strikes, communal conflict, and anti-government violence. In contrast to much of the environmental security literature, it uses a much broader definition of conflict that includes, but is not limited to, organized rebellion. Using a new database of over 6,000 instances of social conflict over 20 years – the Social Conflict in Africa Database (SCAD) – it examines the effect of deviations from normal rainfall patterns on various types of conflict. The results indicate that rainfall variability has a significant effect on both large-scale and smaller-scale instances of political conflict. Rainfall correlates with civil war and insurgency, although wetter years are more likely to suffer from violent events. Extreme deviations in rainfall – particularly dry and wet years – are associated positively with all types of political conflict, though the relationship is strongest with respect to violent events, which are more responsive to abundant than scarce rainfall. By looking at a broader spectrum of social conflict, rather than limiting the analysis to civil war, we demonstrate a robust relationship between environmental shocks and unrest.

Keywords

Africa, conflict, environment, protest, rainfall, rioting

While water is essential for human consumption, agriculture, and industry, a significant share of the world's poor lacks access to clean water, irrigation, sanitation facilities, and hydroelectric capacity. This is especially true in sub-Saharan Africa, where according to the United Nations World Water Development Report (UNESCO, 2009), 340 million people lack access to clean drinking water, 4% of annual renewable flows are stored (compared with 70–90% in developed countries), and less than 5% of cultivated areas are equipped for irrigation. Thus, many countries depend directly on rainfall for crops, livestock, and human consumption, meaning variable access to a critical resource. Flooding and droughts can destroy livelihoods, undermine macroeconomic growth, and place strains on government revenues.

The IPCC warns: 'Climate change and variability are likely to impose additional pressures on water availability, water accessibility and water demand in Africa' (Boko et al., 2007: 435). Erratic rainfall, longer dry periods, and more intense rainfall events are expected to place increased pressure on African agriculture and economies. While some areas of Africa are expected to become drier, others – such as East Africa – are projected

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to become wetter as the climate changes. Most importantly, traditional planting and harvest cycles are likely to be disrupted.

In this article, we examine the relationship between rainfall, water, and sociopolitical unrest in Africa. We are interested in how deviations from normal rainfall patterns – which are linked to droughts and floods – affect political behavior and the propensity of individuals and groups to engage in disruptive activities such as demonstrations, riots, strikes, communal conflict, and anti-government violence. Does the weather influence political disturbances and social conflict? If so, what forms of conflict are most likely? This topic is pressing as the process of global climate change accelerates, potentially making rainfall more unpredictable and severe weather events more common (IPCC, 2007: 49).

Possible links between climate change and conflict have gained considerable attention, including at the United Nations General Assembly (UN, 2009). Some have blamed climatic conditions for particular civil wars, such as Darfur (Faris, 2009). While we eschew simple, direct casual pathways from water resources to civil war and avoid mono-causal explanations for political violence, we argue that water shocks may lead to social conflict via their effects on resource competition, poor macroeconomic outcomes, and reduced state capacity. However, in contrast to many other studies, we do not necessarily expect full-blown civil wars to emerge from water scarcity.[1] Launching an insurgency entails significant start-up costs, planning, and organizational capacity. Moreover, governments must be unable or unwilling to accommodate or repress opposition groups for armed rebellions to emerge. However, grievances and competition over water resources can generate significant social conflict in ways that do not require the level of organization and funding needed for sustaining an insurgency.

Using a new database of over 6,000 instances of social conflict in Africa – the Social Conflict in Africa Database (SCAD) – we examine the effect of deviations from normal rainfall patterns on various types of conflict. Using data on 47 countries from 1990 to 2008, we find that rainfall shocks have a significant effect on both large-scale and smaller-scale instances of political conflict. We find that rainfall correlates with civil conflict and insurgency, although wetter years are more likely to suffer from violent events. Extreme deviations in rainfall – particularly dry and wet years – are associated with all types of social conflict (violent and nonviolent, government-targeted and non/government-targeted), though the relationship is strongest with respect to violent events, which are more responsive to abundant rather than scarce rainfall.

In the next section, we develop a theory of how rainfall and water resources affect political stability, and we present our hypotheses. We then describe SCAD, operationalizations of key variables, and our methods. Following this we discuss our results. In the final section, we offer some concluding remarks on the implications of the findings for theories of violent social mobilization.

Rainfall deviations and conflict

The last decade has seen interest in the relationship between natural resources and conflict. One body of literature argues that the abundance of natural resources – particularly minerals and oil – can lead to political violence (Bannon & Collier, 1999; de Soysa, 2002; Collier & Hoeffler, 2004; Ross, 2004; Humphreys, 2005; Lujala, 2009). Such resources can be looted to fund rebel organizations, resources can lead to friction over their allocation, and dependence on primary commodities can weaken state capacity (Hendrix, 2010). Others scholars have argued that the scarcity of vital resources – particularly water and food – can lead to conflict (Percival & Homer-Dixon, 1996; Hauge & Ellingsen, 1998; Maxwell & Reuveny, 2000; Homer-Dixon, 2001; see Le Billon, 2001 for a review of both literatures). Resource scarcity is argued to generate grievances and fuel conflict over their distribution. These literatures do not necessarily contradict each other, as the former focuses on the availability of lucrative commodities such as gemstones and oil while the latter focuses on basic needs.

With growing concern over the human implications of climate change, many scholars have undertaken quantitative tests of links between environmental scarcity, natural disasters, and civil war. Researchers have tended to look at land and water resources to determine whether or not there is a direct link between scarcity and war (Hauge & Ellingsen, 1998; Homer-Dixon, 2001; Miguel, Satyanath & Sergenti, 2004; Hendrix & Glaser, 2007; Raleigh & Urdal, 2007; Theisen, 2008; Koubi et al., 2012). Yet, there is hardly a consensus about causal relationships, and findings have been weak and inconsistent (Salehyan, 2008). In a related body of work, studies

[1] Others have also noted that human security problems and other forms of unrest, short of international and civil war, may result from environmental factors and resource scarcity (see Barnett & Adger, 2007; Wolf, 1998).

of international conflict find little interstate violence over water and demonstrate that cooperative arrangements are more likely (Wolf, 1998; Toset, Gleditsch & Hegre, 2000; Gleditsch et al., 2006).

In this article, we examine several forms of conflict short of full-blown civil war and state failure. Much of the civil war literature argues that grievances – including over access to water and other resources – are not sufficient to explain armed conflict. While grievances are certainly important, mobilizing a rebellion is a costly and risky endeavor which requires long-term planning, leadership, funding, and sanctuaries to evade government repression (Tilly, 1978; Collier & Hoeffler, 2004; Fearon & Laitin, 2003; Salehyan, 2007). For most aggrieved actors, most of the time, rebellion is not a viable option. In addition, the resort to armed conflict requires that the government be unwilling or unable to reach a compromise with the opposition that is mutually preferred to war (Hegre et al., 2001; Walter, 2009). In the context of resource scarcity, armed conflict does nothing to increase the supply of resources and may indeed diminish it (Maxwell & Reuveny, 2000). Therefore, conflicts arise over the *distribution* of resources rather than their absolute *level*, and distributional issues are inherently part of a political bargaining process.

With this in mind, we argue that extreme deviations from normal rainfall patterns may lead to other forms of social and political disorder short of civil war. Some forms of politically motivated conflict, such as protests and riots, do not require the high levels of organization or funding typical of armed rebellion. In addition, individuals and groups competing for resources may fight directly rather than engage the government, which is often far riskier given the state's preponderance of coercive force. Often times, groups will find neighboring communities, rather than the government, the most appropriate target for making demands; this is especially true if the state is known to be unwilling or unable to redistribute resources in a society. And as Raleigh (2010) argues, communities most vulnerable to climate change are also the least equipped to challenge the government; therefore, conflicts not involving the state may be more likely.

Thus, our analysis is in line with research that argues there may be distinct sets of variables that explain rebellion versus protests and other disturbances (Scarritt & McMillan, 1995; Regan & Norton, 2005), as well as studies that investigate the impact of environmental factors on social violence, such as cattle raiding, that does not fit neatly into the state-centric armed conflict paradigm (Meier, Bond & Bond, 2007; Urdal, 2008; Witsenburg & Adano, 2009). While under certain circumstances and in particular contexts, rainfall deviations may contribute to armed rebellion, we believe that unorganized dissent, mass demonstrations, and communal conflicts are more likely responses.

It should not be assumed that such conflicts are always less significant than armed insurgencies. Indeed, they can be quite disruptive. For instance, following elections in Kenya in 2007 – in which land rights were a major campaign issue – thousands of people died during weeks of rioting and the government was forced to accept a power-sharing deal. In the early 1990s, mass demonstrations in Zambia forced the government of Kenneth Kaunda to accept multiparty elections. In Ghana in 1994, ethnic riots erupted after a dispute in a market, killing approximately 3,000 people and displacing tens of thousands more. While these events are typically less deadly than full-scale civil wars, many cost more lives than many low-level insurgencies and disrupt basic government functions.

The literature on environmental security, which we discuss below, suggests at least five mechanisms through which rainfall deviations may lead to sociopolitical conflict. While negative rainfall shocks imply reduced water availability, drought, and potential crop failure, extreme positive shocks may be equally disruptive as excess rain can lead to crop damage, flooding, mudslides, and increased water-borne disease. We emphasize the importance of extreme events since societies develop expectations about normal rainfall patterns and plan crops and coping strategies accordingly (Reardon & Taylor, 1996). Deviations from normal rainfall disrupt these expectations and can negatively affect human well-being.

First, rainfall deviations may lead to conflict among consumers of water, including those who depend on water as an input for their products. As water stores decline, consumers may come into conflict with one another over access to wells, riverbeds, and the like (Kahl, 2006). Water is a major input for agricultural producers and pastoralists as well as for manufacturing and mining. Thus, farmers, herders, manufacturers, and other producers may come into conflict over water rights and access (Eriksen & Lind, 2009). In addition, rainfall shortages exacerbate the encroachment of deserts into formerly productive land and can lead to increased competition over cropland and pastures.[2]

[2] However, research has found that the Sahel zone is becoming greener after a period of sustained rain and land use change (Olsson, Eklundh & Ardö, 2005).

Second, both excess (i.e. flooding) and shortages of water can lead to price disputes between rural producers and urban consumers. Droughts and damage to cropland after excess rain can lead to temporary food shortages and spikes in market prices. For instance, although weather-related conditions were one of many causal factors (Alexandratos, 2008), the rising price of staple crops in 2008 and 2011 led to massive protests and riots in dozens of countries, especially as urban consumers demanded relief from price inflation. Food price inflation clearly has a negative impact on the welfare of urban dwellers. However, the net impact on rural welfare is ambiguous as small-scale farmers are often net purchasers of food, and some farmers may see a decline in living standards (Barrett & Dorosh, 1996).

Third, as livelihoods in affected areas come under stress, many will opt to migrate to urban areas in search of alternative work. Migration – both within countries and across national boundaries – can lead to intensified competition over jobs, housing, and other resources. It can also lead to shifts in ethnic settlement patterns, which may intensify intercommunal conflict (Suhrke, 1997; Reuveny, 2007). Urban growth also places strain upon governments as demand increases for basic services such as sanitation, electricity, police protection, and roads (Neuwirth, 2005). Thus, migration can create friction between locals and new arrivals as well as place increased demands on providers of local services.

Fourth, states often intervene in markets in order to increase their revenues and expand patronage opportunities. In Africa, market distortions are often very large (van de Walle, 2001). States intervene in the economy through taxation, subsidies, marketing boards, price controls, and trade restrictions, among other means, which are designed by incumbents to maintain political control (Bates, 1989; Krueger, 1996; Kasara, 2007). Given the central importance of agriculture and other water-intensive sectors to African economies, extreme weather events can have particularly pronounced effects for public finance (Benson & Clay, 1998). Natural disasters can place strains on government revenues through the reduction of the tax base as well as increased demands for services and assistance by the hardest hit. Moreover, the ability of incumbents to maintain patronage networks and reward core supporters – either through direct transfers or through manipulating markets – can be undermined. For instance, Robert Bates (1989: ch. 4) discusses how drought in Kenya led to increased demands on the Kenyan Maize Board, an institution which worked primarily to influence food prices, and in turn, political stability. Planning failures caused episodic droughts to turn into major food crises, which ultimately threatened the survival of the regime.

Finally, rainfall variability can have negative macroeconomic effects. Rainfall deviations can present an enormous human and financial toll on developing economies and government resources. Displacement, loss, crop failure, etc., associated with water scarcity and overabundance, can hurt overall economic productivity. Research has shown generally that adverse rainfall shocks have a negative effect on overall growth (Miguel, Satyanath & Sergenti, 2004; Barrios, Ouattara & Strobl, 2008; Jensen & Gleditsch, 2009). General economic malaise may in turn lead to civil conflict and social disorder.

Our expectation is that extreme events *in either direction* make a society more prone to conflict. While many have focused on drought, we also consider the disruptive effect of excessive rain. Moderate increases in rainfall can enhance land productivity; more wealth in a society may lead to more opportunities for looting and theft (Witsenburg & Adano, 2009). However, excessive rain is damaging to agriculture, leading to scarcity and economic contraction (Wilkie et al., 1999; Rosenzweig et al., 2002). Also, floods and mudslides are discrete, rapid-onset disasters that can quickly destroy lives and property, leading to social discontent, particularly if the response is poor.[3] Finally, given that many roads in Africa are unpaved or of poor quality, extreme rain can destroy infrastructure, limiting state capacity to respond to disturbances around the country.

Many of these effects are far-reaching and impact economies and societies as a whole. Recent research has sought to find *local* patterns of conflict and natural disasters by looking for correlations between environmental conditions and conflict at the sub-national level (Buhaug & Lujala, 2005; Buhaug & Rød, 2006; Raleigh & Urdal, 2007). While these studies have revealed many interesting relationships, many of the most significant effects are likely to be felt across the country. For instance, droughts in agricultural regions may lead to migration to urban areas and increased prices for urban consumers; declining state revenues can lead to strains on public finances and negatively affect public-sector employees across the economy; finally, disaster-affected populations can take their protests and demands directly to the national capital. Causal pathways may be long and far-reaching.

[3] As a case in point, our dataset shows protests and riots against the Algerian government following excessive rain and flooding in November 2001, November 2002, and October 2008.

Hypotheses

The discussion above suggests several non-exclusive pathways to sociopolitical conflict. The literature thus far has mainly consisted of theoretical treatments of individual mechanisms, or has provided detailed accounts of a relatively small set of cases. In addition, cross-national, quantitative work has focused primarily on armed conflict (Buhaug, 2010; Burke et al., 2009), rather than a broader array of conflict outcomes. Our contribution is to provide a systematic analysis of the relationship between rainfall deviations and social conflict across the African continent.[4] It is important to first establish a general link between water shocks and sociopolitical instability before validating various causal mechanisms. Environmental security theories suggest that rainfall deviations, defined as extreme deviations from normal rainfall patterns, will increase the likelihood of social conflict. Thus, our main hypothesis is:

> *H1:* Extreme deviations from normal rainfall patterns will increase the frequency of social conflict.

We differentiate between social conflict and armed conflict. The former is the broader category, which includes various forms of contentious behavior. Social conflict includes peaceful protests, rioting, strikes, mutinies, and communal violence. Armed conflict is a subset of social conflict, requiring organized, armed violence against the government or between governments, in the case of international war. As we have argued above, armed conflict may not be the most likely consequence of environmental disasters. Given the large costs and risks associated with challenging the state, we expect interpersonal and intercommunal violence to be the norm, rather than direct opposition to governmental authorities. Nonetheless, we also examine the effect of rainfall deviations on civil wars and insurgencies.

Scholars note that low legitimacy and weak capacity characterize many African states (Herbst, 2000; Van de Walle, 2001). Many African governments have also proven unable to contain conflict in peripheral areas (Meier, Bond & Bond, 2007; Obioha, 2008). Given our focus on Africa, we expect particular forms of social conflict when societies are faced with extremes in rainfall. Therefore, we disaggregate our social conflict indicator into various types to test a pair of additional hypotheses. First, because regimes with low legitimacy and accountability may be less responsive to peaceful protest, we expect violent conflict to be more sensitive to rainfall deviations than non-violent conflict. As Lichbach (1987) argues, a history of regime repression makes actors more likely to turn to violent strategies. Given the poor record of many African regimes, opposition groups may perceive their governments to be unwilling to accommodate peaceful demands and thus turn to violence. Second, African states are often seen as unwilling or unable to redistribute resources in society, smooth income shocks resulting from environmental stress, and contain peripheral violence. Therefore, because the government may not be the most appropriate target, we expect social actors to come into conflict with one another, rather than challenge the state.

> *H2:* Extreme deviations from normal rainfall patterns will increase the frequency of violent conflict more than the frequency of nonviolent protest.

> *H3:* Extreme deviations from normal rainfall patterns will increase the frequency of nongovernment targeted action more than the frequency of actions targeting the state.

Data and methods

The dependent variables: Social conflict and armed conflict

We test for the effect of climatic factors on six different dependent variables: civil conflict onset, total events, nonviolent events, violent events, government-targeted events, and nongovernmental events. Civil conflict onset is a dummy variable that takes a value of 1 if the country-year contained the onset of an intrastate conflict characterized by 25+ annual battle deaths, and 0 otherwise. These data are from the UCDP/PRIO Armed Conflict Dataset, updated through 2009 (Gleditsch et al., 2002; Harbom & Wallensteen, 2010).

All of the event variables are counts of the number of events in a given year. These are from the Social Conflict in Africa Database (SCAD),[5] which contains information on instances of contentious action such as *protests*, *riots*, and *strikes*; but it also includes *intra-governmental violence*, such as coups or factional fighting within the military; violent *repression* by the government or its agents; *anti-government violence* that does not meet the conventional thresholds for civil conflict (as defined by the Armed Conflict Dataset); and *extra-governmental violence*, or violence by a non-state, organized militant group against individuals, rival communal groups, or other social actors not involving the state.[6] Every country

[4] Unlike Miguel, Satyanath & Sergenti (2004) and Hendrix & Glaser (2007), we analyze North African cases as well.

[5] http://www.scaddata.org. See website for codebook.

[6] See the codebook for a full description of the different event types.

Table I. Social conflict events in 47 African countries, 1990–2009

Variable	*Obs.*	*Mean*	*Std. dev.*	*Min.*	*Max.*
Civil conflict onset	937	0.06	0.24	0	1
Total events	937	6.66	11.18	0	95
Nonviolent events	937	3.62	5.50	0	42
Violent events	937	3.05	6.65	0	67
Government–targeted events	937	3.55	5.49	0	40
Non–government–targeted events	937	3.12	6.95	0	74

Figure 1. Social conflict events in Africa, 1990–2009

in Africa (with a population greater than one million), including North Africa, is coded for the period 1990–2009. The data are compiled from Associated Press and Agence France Presse newswires and contain detailed information about event duration, magnitude, the actors and targets involved, state repression, issues, and locations. A total of 6,305 distinct events have been coded. These events do not include, however, violent events that occur during periods of armed conflict that are directly related to the conflict dynamic. Individual battles within civil conflicts are coded in the Armed Conflict Location and Event Dataset (ACLED) (Raleigh et al., 2010).

Total events are all events for a country-year across event types. *Nonviolent events* are those events, such as protests and strikes, which are not intended to cause damage to people or property. *Violent events*, such as riots, government repression, anti-government violence, and both intra- and extra-governmental violence, are those in which the actor initiating the event acted to cause injury to people or property. *Government-targeted events* are those where the central or a regional government was a target. Finally, *non-government-targeted events* are those where the targets are nongovernmental entities. Descriptive statistics for our dependent variables are presented in Table I. Figure 1 displays the distribution of social conflict events in Africa over time. Civil conflict onsets are rare, occurring in 6% of country-year observations, while the average country-year experienced roughly seven social disturbance events.

Independent variable: Rainfall deviations

Our measure of rainfall deviations is the annual standardized *rainfall deviation* from the long-term (1979–2008) panel mean of rainfall for a given country.[7] Our measure is based on the Global Precipitation Climatology Project

[7] We include data prior to our time frame above in order to include more observations for calculating means and standard deviations and reduce the influence of outliers.

(GPCP) database of monthly rainfall estimates, version 2.1, aggregated at the country-year level. The data have 2.5° latitude by 2.5° longitude native resolution and cover the period 1979–2008. Because the data combine measurements from remote-sensed sources and rain gauges, they are more accurate and less affected by human factors than gauge-based estimates alone. To generate our standardized *rainfall deviation* variable, we measure deviations from the long-term means for a given country and divide them by the panel's standard deviation.[8] Values for standardized *rainfall deviation* have a mean of 0.05 (near zero), a standard deviation of 1, and range from –3.74 to 3.91. This measure more accurately accounts for cross-sectional differences in both mean values for rainfall, which range from 3.1 cm/yr (Egypt) to 233.3 cm/yr (Sierra Leone), and within-panel variance, measured by the variation coefficient, which ranges from 0.05 (Democratic Republic of Congo) to 0.27 (Botswana). We test for both linear and curvilinear relationships between the standardized *rainfall deviation* and disturbance events by running the analysis with both the linear measure and its squared term. We expect very low and very high rainfall years to be associated with conflict.[9]

Several studies of rainfall and conflict (Miguel, Satyanath & Sergenti, 2004; Hendrix & Glaser, 2007; Jensen & Gleditsch, 2009) operationalize rainfall shocks as the percentage change in annual rainfall in country *i* in year *t* from the previous year. As a measure of whether or not a given country-year was a particularly wet or dry year, this can be misleading (Ciccone, 2011). While the two variables are positively correlated ($r = 0.62$), it is clear that a year with zero increase following an unusually wet year would still be an unusually wet year, while a year of 50% rainfall growth following an unusually dry year might still be a less-than-average year. For this reason, our *rainfall deviation* more accurately measures relative rainfall abundance, given historical expectations for that country.

Several measures of environmental scarcity, such as deforestation or unclean water, may be endogenous to human activity and political processes. While global rainfall is expected to change due to anthropogenic forcing, in the proximate sense rainfall is independent of human activity: on a yearly basis, the level of development or social conflict in a country cannot 'cause' the amount of rainfall. Thus, endogeneity between our independent and dependent variables is not a concern. Moreover, this should mitigate the risk of omitted variable bias since it is unlikely that unmodeled features of a country would affect both conflict and precipitation.[10]

Controls

While omitted variables should not be of great concern, we include a number of additional variables for comparison purposes. We employ a battery of controls typical to the literatures on protest and civil conflict. First, we control for regime type. Many studies have found an inverted-U shaped relationship between regime type and various contentious outcomes: political protest and violence are least common in highly authoritarian regimes and in full democracies (Muller & Weede, 1990; Hegre et al., 2001). To model the inverted-U hypothesis, we include the revised combined Polity score, commonly referred to as *Polity2*, and its squared term. *Polity2* ranges from –10 (full autocracies) to 10 (full democracies).[11]

Second, we control for level of development and economic growth. The negative relationship between economic development and civil conflict is the most robust finding to emerge from the conflict literature (Hegre & Sambanis, 2006). Moreover, various studies indicate that economic growth is associated with a decrease in political violence and protest (Collier & Hoeffler, 2004; Miguel,

[8] More formally, this is $(X_{it} - \bar{X}_i)/\sigma_i$, where $\bar{X}_i$ is the panel mean for country *i*, X_{it} is the current rainfall in time *t* for country *i*, and σ_i is the standard deviation for country *i*.

[9] Extreme values of *rainfall deviation* are few: only 42 country-years (out of 935) have rainfall deviation values either greater than 2 or less than –2. Large deviations are rare, but their rareness is accounted for in the estimation of standard errors and estimated confidence intervals for predicted probabilities of onset/counts of events.

[10] Several studies of rainfall and conflict (Miguel, Satyanath & Sergenti, 2004; Jensen & Gleditsch, 2009; Koubi et al., 2012; Ciccone, 2011) use an instrumental variables approach, in which rainfall is used as an instrument for economic growth. Dunning (2008) criticizes this approach on the grounds that different components of growth could have countervailing effects on conflict, and that including rainfall as an instrument only captures one aspect of economic growth. Moreover, these studies assume that national-level economic growth rates are a plausible proxy for personal incomes and the opportunity cost to participating in violence, and that the effect of rainfall is through growth rather than directly on conflict. In much of Africa, where the small-scale agricultural sector provides the majority of employment but few cash crops and mineral exports drive export earnings and growth statistics, rainfall is a better proxy for societal grievances and opportunity cost. The instrumental variables approach precludes us from testing this possibility directly.

[11] As per the *Polity IV Dataset Users' Manual*, standardized authority scores are handled in the following manner: –66 (cases of foreign interruption) is treated as 'system missing'; –77 (cases of interregnum) is treated as 0; –88 (cases of regime transition) is the difference between the beginning and ending Polity code, prorated for the duration of the transition (Marshall & Jaggers, 2009).

Satyanath & Sergenti, 2004; Hendrix, Haggard & Magaloni, 2009). Data are from the Penn World Table version 6.3 (Heston, Summers & Aten, 2009).

Third, we control for population and population growth. For any given level of grievance, we would expect that larger populations would see more political protest (Fearon & Laitin, 2003). Population growth is included to control for the possibility that countries undergoing rapid demographic transformation will be more prone to political disorder (Urdal, 2005). Countries with large populations and large economies may also have greater news coverage, making these controls important to include. Data are from the Penn World Tables version 6.3 (Heston, Summers & Aten, 2009).

Finally, in models that use SCAD as our dependent variable, we control for the incidence of civil conflict. Reporting on civil conflict might 'crowd out' reporting on other forms of contentious collective action, and under some circumstances the conflict itself may make the expression of popular grievance more risky. However, conflicts themselves are often the cause of large-scale protest (as in Rwanda in 1995 and Liberia in 2001 and 2003). Thus, the expected effect of civil conflict is indeterminate.

Estimation and results

For modeling civil war/insurgency, we use logistic regression with errors clustered at the country level and a count of years since last conflict along with its squared and cubic terms (Carter & Signorino, 2010).[12] For modeling the SCAD event data, because the distribution of events is highly skewed, we use negative binomial regression. Negative binomial models are similar to other event count models, such as Poisson regression, but are more appropriate for over-dispersed data.

We estimate the event count models with a lagged dependent variable and robust standard errors clustered on countries. As a robustness check, we include conditional country fixed effects. The conditional fixed-effects model converts observed values for the dependent and independent variables into deviations from their mean values within each unit, thus eliminating the cross-sectional elements from the data. The estimated coefficients report only longitudinal changes within countries. This also accounts for unmodeled attributes of the country as a whole, and for the fact that some countries may have greater news coverage than others. We also use year dummies to control for factors that might affect levels of disturbances across all countries in a given year. The civil conflict onset model is run on a sample of 47 countries for the years 1991–2008, while event count analyses are run on a sample of 46 countries for the years 1991–2007.[13]

Table II reports logit coefficient estimates of the effects of our various climatic shock variables on civil conflict onset. Model 1 includes the both the linear and squared *rainfall deviation* measures, the lag of the rainfall measures, and a battery of lagged control variables. The present effect of *rainfall deviation* is positive. The positive, linear effect of present *rainfall deviation* is strongly statistically significant ($p < 0.01$) and the marginal effect is large in percentage terms. Holding all the control variables at their mean, a one standard deviation increase from mean rainfall increases the probability of conflict onset from 0.038 to 0.055, an increase of 44.7%; a two standard deviation increase from mean rainfall increases the probability of conflict onset by 116%. One and two standard deviation decreases from mean rainfall are associated with –30.2% and –50.3% decreases in the probability of onset, respectively.

Contrary to some arguments in the literature, increased rainfall, rather than water scarcity, increases the probability of conflict onset. Moreover, we find no evidence of a curvilinear effect. This finding confirms two previous studies using civil conflict as the dependent variable. Buhaug (2010: Model 7) finds that rainfall is positively related to the onset of low-level civil conflict (using a 25 battle deaths threshold). Burke et al. (2010: Table 3, Model 3) find some evidence for a positive correlation between contemporaneous rainfall and the incidence of civil conflict.[14]

[12] As opposed to the event count models discussed below, we do not use fixed effects logit to estimate civil conflict onset. This is because a fixed-effects estimator is inappropriate in situations where there is no variation in the dependent variable as the fixed effect is perfectly collinear with the DV. Many of our cases never experience a civil conflict onset and would drop out of the analysis.

[13] Somalia is excluded from the event count analysis for two reasons. First, the dynamics addressed in our theoretical argument presume at least a minimally functioning state, which Somalia lacks. Second, patterns of conflict in Somalia have been driven by interactions with intervening third parties (the USA and UN forces in the early 1990s, Ethiopia more recently). The inclusion of Somalia somewhat diminishes the explanatory power of our various models.

[14] Along with our analysis, these two studies examine the direct effect of rainfall on civil conflict. Others (Miguel, Satyanath & Sergenti, 2004; Jensen & Gleditsch, 2009; Koubi et al., 2012) use rainfall as an instrument for economic growth before estimating effects on conflict, or employ other dependent variables such as regime transitions (Brückner & Ciccone, 2011). These differences in modeling choices have led to somewhat divergent findings, although they are often not directly comparable.

Table II. Rainfall deviations and civil conflict onset, 1991–2008

Variable	*(1)*
Lagged DV	–2.494***
	(0.689)
Rainfall deviation	0.405***
	(0.156)
Rainfall deviation^2	–0.077
	(0.069)
Rainfall deviation, lagged	–0.101
	(0.151)
Rainfall deviation^2, lagged	–0.043
	(0.088)
Polity2, lagged	0.013
	(0.031)
Polity2^2, lagged	–0.010
	(0.009)
log Population, lagged	0.079
	(0.110)
Population growth, lagged	0.014**
	(0.006)
log Real GDP per capita, lagged	–0.191
	(0.288)
Real GDP growth, %, lagged	–0.004
	(0.010)
Constant	–0.425
	(2.157)
Controls for temporal dependence	Yes
Observations	828
Countries	47

Robust standard errors, clustered on countries, in parentheses. * significant at 10%, ** significant at 5%, *** significant at 1%.

None of the standard controls in the civil conflict literature are significant in the model, including level of economic development and rates of economic growth. Contrary to Urdal (2005), we find some evidence that population growth is positively related to conflict onset. A one standard deviation increase in population growth from the mean value is associated with a 32.3% increase in the probability of onset in the following year.[15]

Turning to our event data, Table III reports coefficient estimates of the effects of *rainfall deviation* on our five dependent variables. Even-numbered models are estimated on the pooled time-series cross-sectional (TSCS) sample with standard errors clustered on countries. Odd-numbered models are estimated with conditional fixed effects.

The TSCS findings indicate a U-shaped relationship between contemporaneous *rainfall deviation* and all five dependent variables: all five coefficient estimates are statistically significant (in joint tests) and positive. In terms of magnitude and strength of effect, the largest is on *violent events*, with a one-unit increase in *rainfall deviation* from the panel mean associated with a 0.084 increase in the difference in the log of expected counts (significant at $p < 0.01$), followed by *government-targeted events* (0.074, $p < 0.01$), *total events* (0.072, $p < 0.01$), and *nonviolent events* (0.068, $p < 0.01$). The statistical significance of effect is slightly lower for *non-government-targeted events* (0.072, $p < 0.05$).

The results of the conditional fixed-effects models largely corroborate the TSCS results, save for the effect of *rainfall deviation* on *nonviolent events* and *non-government-targeted events*. Both the coefficient estimates and levels of statistical significance are somewhat smaller. Lagged *rainfall deviation* is only weakly associated with *non-government-targeted events*, with the linear and square terms failing a joint significance test, contrary to our expectations in Hypothesis 3.

Our control variables performed inconsistently. Our findings lend some support to the inverted-U relationship between regime type and social conflict: *Polity2-squared* is negatively associated with *total events*, *violent events*, and *non-government-targeted events*, though the relationship is only significant under fixed-effects specifications. This indicates that institutional coherence explains variation in social conflict within countries better than variation across countries. It also indicates that political institutional coherence matters more for deterring violent rather than nonviolent mobilization, a finding consistent with the literature (Muller & Weede, 1990; Hegre et al., 2001). *GDP growth* is negatively associated with all event types, though the levels of statistical significance vary from model to model. Unsurprisingly, more populous countries are characterized by more social conflict events across model specifications. If anything, population growth is associated with less social conflict, though high levels of social conflict may lead to outmigration.

We use the CLARIFY software (King, Tomz & Wittenberg, 2000) to estimate the effect of changes in *rainfall deviation* on the quantities of interest: expected counts of events. Holding all control variables at their mean values, a two standard deviation increase from mean rainfall is associated with a 30.68% increase in expected *total events*, while a two standard deviation decrease in rainfall deviation is associated with a 38.09% increase in expected *total events*. A three standard deviation increase

[15] Environmental scarcity theories focus on the potential for population growth to lead to conflict as resources become scarcer on a per capita basis. See Kahl (2006) for a discussion.

Table III. Rainfall deviations and social conflict events, 1991–2007

	(2)	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*
Variables	*Total events*		*Nonviolent events*		*Violent events*		*Government–targeted*		*Non–government–targeted*	
Lagged DV	0.049***	0.019***	0.093***	0.033***	0.081***	0.029***	0.091***	0.034***	0.080***	0.026***
	(0.009)	(0.002)	(0.015)	(0.005)	(0.015)	(0.004)	(0.014)	(0.005)	(0.019)	(0.004)
Rainfall deviation	–0.015	–0.016	–0.042	–0.025	0.032	0.011	–0.012	0.003	–0.023	–0.017
	(0.032)	(0.028)	(0.039)	(0.033)	(0.035)	(0.039)	(0.043)	(0.034)	(0.037)	(0.037)
Rainfall deviation^2	0.072***	0.046**	0.068***	0.031	0.084***	0.061**	0.074***	0.044**	0.072**	0.021
	(0.018)	(0.018)	(0.021)	(0.022)	(0.026)	(0.025)	(0.025)	(0.022)	(0.031)	(0.025)
Rainfall deviation, lagged	–0.018	–0.007	–0.027	–0.026	0.014	0.024	–0.058	–0.035	0.044	0.073*
	(0.038)	(0.030)	(0.035)	(0.034)	(0.056)	(0.042)	(0.042)	(0.035)	(0.049)	(0.038)
Rainfall deviation^2, lagged	0.015	0.033	0.002	0.023	0.033	0.035	–0.003	0.019	0.039	0.028
	(0.028)	(0.021)	(0.026)	(0.024)	(0.040)	(0.031)	(0.029)	(0.025)	(0.034)	(0.027)
Polity2	–0.015	–0.004	–0.017	–0.007	–0.003	0.014	–0.016	–0.009	–0.002	0.028*
	(0.012)	(0.011)	(0.012)	(0.012)	(0.014)	(0.014)	(0.013)	(0.012)	(0.015)	(0.015)
Polity2^2	–0.000	–0.005***	0.003	–0.002	–0.005	–0.009***	0.001	–0.004*	–0.003	–0.011***
	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)
log Population	0.331***	0.164**	0.290***	0.109	0.439***	0.207**	0.276***	0.056	0.494***	0.429***
	(0.062)	(0.080)	(0.053)	(0.094)	(0.075)	(0.100)	(0.058)	(0.091)	(0.092)	(0.120)
Population growth, %	–4.134*	–1.770	–3.894	–1.723	–4.747**	–1.253	–4.733	0.326	–4.563**	–2.826
	(2.112)	(2.311)	(2.442)	(2.365)	(2.213)	(3.525)	(2.918)	(2.731)	(2.096)	(2.948)
log GDP per capita	–0.107	0.049	–0.090	0.104	–0.116	–0.046	–0.105	0.136	–0.058	0.058
	(0.074)	(0.097)	(0.079)	(0.113)	(0.079)	(0.125)	(0.087)	(0.116)	(0.113)	(0.122)
Real GDP growth, %	–0.012**	–0.007*	–0.009	–0.007	–0.017**	–0.007	–0.013**	–0.004	–0.013*	–0.009*
	(0.005)	(0.004)	(0.006)	(0.005)	(0.007)	(0.005)	(0.006)	(0.004)	(0.008)	(0.005)
Civil conflict incidence	0.055	–0.025	0.123	0.082	–0.046	–0.251*	–0.018	0.002	0.136	–0.037
	(0.098)	(0.095)	(0.095)	(0.109)	(0.152)	(0.131)	(0.107)	(0.113)	(0.153)	(0.118)
Time trend	–0.017	–0.003	–0.024	–0.004	–0.011	–0.008	–0.023	–0.010	–0.008	–0.007
	(0.014)	(0.011)	(0.017)	(0.013)	(0.016)	(0.016)	(0.017)	(0.013)	(0.013)	(0.014)
Constant	33.648	5.405	46.372	6.830	19.034	14.289	45.737	19.478	11.842	10.794
	(28.782)	(22.823)	(33.231)	(25.891)	(31.003)	(31.055)	(34.121)	(26.724)	(25.266)	(28.647)
Observations	765	765	765	765	765	765	765	765	765	765
Countries	46	46	46	46	46	46	46	46	46	46
Period dummies?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects?	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Clustered errors?	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No

Standard errors in parentheses; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table IV. Marginal effects of rainfall deviations on social conflict

	Total events	*Nonviolent events*	*Violent events*	*Government-targeted*	*Non-government-targeted*
– 3 Standard deviations	103.5%	109.9%	98.5%	108.0%	107.4%
– 2 Standard deviations	38.1%	42.2%	31.9%	38.6%	39.4%
– 1 Standard deviation	9.2%	11.3%	5.3%	9.0%	9.8%
+ 1 Standard deviation	6.1%	2.8%	12.6%	6.5%	4.8%
+ 2 Standard deviations	30.7%	21.4%	51.2%	32.0%	27.2%
+ 3 Standard deviations	88.2%	66.2%	145.0%	92.8%	82.2%

in *rainfall deviation* is associated with an 88.19% increase in expected *total events* from the mean, while a three standard deviation decrease is associated with a 103.49% increase in expected *total events* from the panel mean. Thus, *total events* are more somewhat more sensitive to negative rainfall deviations than positive ones. Figure 2 depicts this curvilinear relationship.

Hypotheses 2 and 3 suggest *violent conflict* and *non-government* conflict to be more sensitive to rainfall shocks. We find evidence in support of Hypothesis 2. The link between *rainfall deviation* and *violent events* is significant under both TSCS and fixed effects specifications, while it is only significant for *nonviolent events* under the TSCS specification. The evidence for a link between violent conflict and rainfall patterns is thus more robust.

Rainfall appears to have differential effects on violent and nonviolent social conflict. Table IV reports marginal effects of *rainfall deviation* on percentage changes in expected events from the panel mean value for the five event types. For both violent and nonviolent social conflict, deviations from mean rainfall levels in both directions are associated with increased incidence of social conflict. The magnitude of the effect for nonviolent protest is roughly twice as large for negative rainfall shocks as for positive ones. Peaceful mobilizations, such as demonstrations and labor actions, are more prevalent in response to rainfall scarcity than rainfall abundance. The relationship for *violent events* is the opposite: the marginal effect for positive rainfall shocks is larger than that for negative ones. Taken with the findings from our analysis of civil conflict onset data, we show that political violence is more likely in wetter years.

We find less support in favor of Hypothesis 3, however. We expected rainfall deviations to have a larger effect on non-government-targeted events, given the perceived inability of many African regimes to meet social demands or contain peripheral conflict. However, our findings show that rainfall shocks have similar effects on non-governmental and government-targeted conflict, though the findings are less robust for *non-government-targeted events*. Rainfall shocks have roughly similar effects on *government-targeted events* and *non-governmental events*, with a two standard deviation drop in rainfall increasing the former by 38.6% and the latter by 39.4%. The marginal effect of positive rainfall shocks is somewhat larger for *government-targeted events*. Therefore, African publics do make increased demands upon both state and private actors.

In additional models, we investigated the potential for the effect of *rainfall deviations* being contingent on level of development, the size of government, and level of agricultural dependence, as these are factors commonly cited as reasons for expecting strong environment and conflict links in Africa. Our analysis reveals the effects are roughly equivalent across lower- and higher-income, and less agriculturally-dependent and more agriculturally-dependent African countries, with the effect being slightly larger at higher levels of income, smaller government size, and higher levels of agricultural dependence. However, there is a relatively limited range within Africa. For regression output and expanded discussion, see Appendix 2 (published online).

Our results suggest several main findings. First, we find some evidence that rainfall correlates with civil war and insurgency, although conflict outbreak is more likely in wetter years. This may be due to tactical considerations: violent actors may be less likely to launch campaigns when there are severe water shortages, making it difficult to care for combatants in the field, and they will be more vulnerable when there is less foliage to provide cover (Meier, Bond & Bond, 2007; Witsenburg & Adano, 2009). During periods of extreme scarcity (i.e. drought), people may be more concerned with survival rather than fighting. Also, too much rain can also destroy infrastructure, particularly unpaved roads, thereby limiting government ability to respond to violence.

Second, very high and very low rainfall years increase the likelihood of all other types of political and social

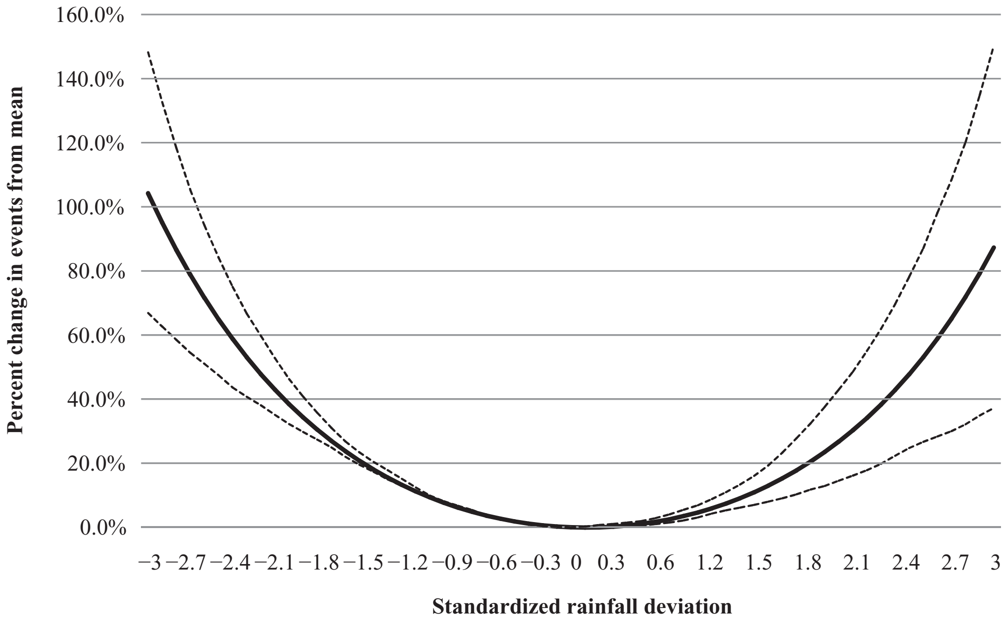

Figure 2. Marginal effect of rainfall deviations on total social conflict events
The solid line is the estimated percent change; the dashed lines represent the estimated 95% confidence interval. Marginal effects estimated using CLARIFY (King, Tomz & Wittenberg, 2000).

conflict, confirming our main hypothesis. Extremes in rainfall have large effects across the board on all types of political conflict, though the relationship is strongest with respect to violent events, which are more responsive to abundant rainfall. Using data from Kenya, Theisen (2012) also finds that wetter years are associated with more violence. Future research must explore whether this increase in violence is due to the looting of abundant resources, the damaging effects of floods, or both.

Third, we find that rainfall scarcity and excess have differential impacts across the various types of social conflict events. All types of events are more numerous in extreme years than in years of average rainfall. Violent events – such as riots, communal violence, and factional conflict within the government – are more prevalent in abnormally high years of rainfall than abnormally low ones. Non-violent events, such as protest and strikes, are almost twice as sensitive to rainfall scarcity as abundance. Somewhat surprisingly, we find that rainfall shocks have roughly equal impacts on government-targeted and non-government-targeted social conflict. Though African states may be comparatively weak, they are still a focal point for popular discontent.

Conclusions

We have demonstrated a curvilinear relationship between rainfall and social conflict. We have also demonstrated the importance of looking at various forms of conflict, including, but not limited to, civil war and insurgency. While armed conflict is more likely to break out in wetter years, we show that other forms of conflict are strongly influenced by extreme positive and negative deviations from normal rainfall. While we have not provided evidence from other regions, Africa may be especially sensitive to rainfall shocks, given the dependence of many African economies on agriculture.[16] Given low adaptive capacity across the continent, climate change effects are likely to be pronounced in Africa.

Given concerns about climate change, what does this study imply for the future? The IPCC climate scenarios generally agree that northern and southern Africa will become significantly dryer, while eastern Africa will be significantly wetter. Moreover, rainfall will become clumpier, with more of it coming all at once – leading to flooding and runoff – with longer dry periods in between. Thus, mean levels of rainfall will change, but so will variance: extreme rainfall events may become much more common. If the historical relationship between social conflict and rainfall continues, the future will likely see more social conflict. Therefore,

[16] See Koubi et al. (2012) and Hendrix & Salehyan (2011) for discussions of the climate–conflict link in Africa in a more broadly comparative context.

policymakers should focus on ways to cushion rainfall shocks through improving water storage capacity and irrigation systems, introducing improved varieties of seeds, providing access to insurance markets, and preventing flood damage. It is also important to promote accountable, transparent government institutions to better meet citizen demands through regular, peaceful means.

Data replication

The dataset and do-files for the empirical analysis in this article can be found at http://www.prio.no/jpr/datasets.

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Appendix 1: List of countries included in the analysis

Country	*Total events, 1990–2009*	*Country*	*Total events, 1990–2009*
Algeria	201	Malawi	115
Angola	57	Mali	48
Benin	57	Mauritania	79
Botswana	14	Mauritius	8
Burkina Faso	56	Morocco	91
Burundi	107	Mozambique	48
Cameroon	79	Namibia	21
Central African Republic	124	Niger	176
Chad	50	Nigeria	855
Cote D'Ivoire	234	Republic of Congo	36
Democratic Republic of Congo	327	Rwanda	58
Egypt	300	Senegal	80
Eritrea	11	Sierra Leone	84
Ethiopia	63	Somalia	331
Gabon	53	South Africa	801
Gambia	11	Sudan	226
Ghana	74	Swaziland	57
Guinea	62	Tanzania	77
Guinea-Bissau	49	Togo	72
Kenya	307	Tunisia	29
Lesotho	54	Uganda	68
Liberia	89	Zambia	117
Libya	50	Zimbabwe	336
Madagascar	62		

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