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Sustained drought, vulnerability and civil conflict in Sub-Saharan Africa

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ABSTRACT

With climate change projections indicating a likely future increase in extreme weather phenomena, it is an urgent matter to assess the effect of drought on civil conflict. However, studies of this relationship so far provide inconclusive findings. One reason for this inconsistency is that existing research has not sufficiently taken into account the local vulnerability and coping capacity that condition the effect of drought. In particular, the exposure to sustained droughts undermines alternative coping mechanisms of individuals. Moreover, reliance on rainfed agriculture for income and food provision renders individuals particularly vulnerable to droughts. Based on these observations, I suggest that areas experiencing sustained droughts or depending on rainfed agriculture are more likely to see civil conflict following drought as individuals in these regions are more likely to partake in rebellion in order to redress economic grievances or to obtain food and income. Using novel high-resolution data on civil conflict events in Sub-Saharan Africa from 1989 to 2008, this paper evaluates the relationship between sustained drought, rainfed agriculture and civil conflict violence at the subnational level. In line with the argument, areas with rainfed croplands see an increased risk of civil conflict violence following drought. There is also some support for the proposition that areas experiencing sustained droughts have a higher risk of conflict. The results are robust to a wide range of model specifications.

Introduction

Mounting evidence for climate change has given rise to a growing body of research on the security implications of an increase in extreme weather events like droughts. Climate variability and change may leave millions of people exposed to increased water stress (Boko et al., 2007). Water scarcity is one of the core issues of concern, in particular for Sub-Saharan Africa, where presently about one third of the population lives in drought-prone areas (Boko et al., 2007). Projections for the future remain surrounded by uncertainty, but an increase in drought is deemed likely in presently dry regions by the end of the century (Solomon et al., 2007).

Common worries are that drought or other extreme climatic events may serve as catalysts for conflicts over food and water and trigger regional and ethnic tensions to escalate into violent clashes (CNA, 2014). However, in contrast to popular belief, the scientific evidence for the link between climate variability and rebellions is inconclusive and evidence for a direct link is rather weak (Theisen, Gleditsch, & Buhaug, 2013). One reason for this inconclusiveness may be that previous empirical assessments have not sufficiently taken into account relevant local conditions under which drought and other extreme climatic events can be expected to have a measurable impact on the onset and dynamics of civil conflict. Whereas most research has focused on a direct link on an aggregate country level, the effect of climate variability on livelihoods and, thereby, on the propensity for violence is likely to be dependent on the local vulnerability and coping capacity.

Along these lines, this paper moves beyond the focus on direct and immediate effects to focus on factors that reduce coping capacity, drawing on the literature on disaster risk reduction. According to this literature, the exposure to sustained droughts undermines alternative coping mechanisms of individuals. Moreover, reliance on rainfed agriculture for income and food provision renders individuals particularly vulnerable to droughts. Based on these observations, I suggest that areas experiencing sustained droughts and depending on rainfed agriculture are more like to see

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civil conflict, as individuals in these regions are more likely to partake in rebellion to redress economic grievances or simply to obtain food and income.

The paper empirically evaluates the relationship between drought, rainfed agriculture and civil conflict violence at the subnational level covering Sub-Saharan Africa in the time period 1989–2008. The results suggest that areas with rainfed croplands see an increased risk of civil conflict violence following drought. There is also some support for the proposition that areas experiencing sustained droughts have a higher risk of conflict. The results are robust to a wide range of model specifications, including controls for time-invariant heterogeneity among units and spatial dependence, as well as different specifications of key variables.

The paper proceeds with a section reviewing existing research on climate variability and civil conflict. I then develop propositions related to why, how and when droughts are most likely to lead to civil conflict violence. I move on to test these propositions. Finally, I draw conclusions and point to areas for future research.

Previous research

Africa is often held to be particularly vulnerable to political instability resulting from climate change, as dependence on rainfed agriculture, widespread poverty and low institutional coping capacity limit the continent's adaptive capacity (Boko et al., 2007). Climate change will amplify existing stress on water resources and is very likely to reduce crop productivity (Niang et al., 2014). This could potentially have an impact on a wide range of social phenomena such as interpersonal conflict, violence between communal pastoralist and farming groups, and civil conflict (Fjelde & von Uexkull, 2012; Hsiang & Burke, 2013; Hendrix & Salehyan, 2012). In this paper, I focus on intrastate armed conflict, here synonymously referred to as rebellion or civil conflict, where governments are fought by one or more rebel groups (Gleditsch, Wallensteen, Eriksson, Sollenberg, & Strand, 2002). This type of conflict has grave social and political consequences and has received major attention in the debate about the security implications of climate variability and change (IPCC, 2014).[1]

Research has focused on links between the onset and intensity of conflict and different dimensions of climate variability, which are the mean state of precipitation, temperature and the occurrence of extremes like drought (IPCC, 2014). However, while the body of literature empirically studying linkages between climate variability and civil conflict is rapidly expanding, the findings are inconclusive (Hsiang & Burke, 2013; Scheffran, Brzoska, Kominek, Link, & Schilling, 2012; Theisen et al., 2013). Most previous research has focused on direct links at the country level and, overall, findings are mixed. Burke, Miguel, Satyanath, Dykema, and Lobell (2009) do not find a significant effect of rainfall, but they suggest that higher temperature increases the risk of major civil wars in Sub-Saharan Africa. These findings contrast with those of Couttenier and Soubeyran (2014) and Buhaug (2010), who do not find a significant relationship between high temperatures and conflict. Yet, several studies do provide some evidence for the expected conflict-driving effect of droughts and rainfall anomalies. Notably, in a country-level analysis focusing on Africa, Couttenier and Soubeyran (2014) find a weak positive link between drought and civil war. Similarly, Nel and Righarts (2008), in a study with global coverage, find that climatic disasters – including droughts, storms, floods and extreme temperatures – have a positive impact on the onset of conflict. Miguel, Satyanath, and Sergenti (2004) maintain that a decrease in rainfall from the previous year, as an instrument for negative economic growth, increases the probability of intrastate conflict in Sub-Saharan Africa. In contrast, Hendrix and Salehyan (2012) find that wetter years are associated with a higher risk of civil conflict onset at the country level.

Aggregate measures of environmental factors used in these contributions may mask local variations in weather extremes and civil conflict violence, which both usually affect a limited area in a country. Thus, a subnational level of analysis is arguably more suitable for the study of spatially limited phenomena. A handful of recent studies have moved to assess the link between climate and civil conflict using subnational data. However, the findings remain inconclusive. In a study covering the African continent, Theisen, Holtermann, and Buhaug (2011) neither find evidence for a direct impact of drought on the location of onset of civil conflict, nor evidence for an effect conditioned by the political exclusion of ethnic groups, infant mortality rates, population or regime type. A similar study on Asia arrives at the same conclusions (Wischnath & Buhaug, 2014). However, these studies focus exclusively on the point location of one event marking the onset of the conflict. It is not clear how such an operationalization necessarily captures the link between drought and civil conflict violence. Three recent studies show some support for a subnational link between climate variability and civil conflict violence in East Africa. Raleigh and Kniveton (2012) show that rebel violence is more likely in anomalously dry periods of the year, in a study of sub-national variation in conflict events in East Africa. According to Maystadt and Ecker (2014) drought drives local variations in conflict in Somalia through its impact on livestock prices. O'Loughlin et al. (2012) conclude that higher levels of rainfall decrease the risk of violence in East Africa, while higher temperatures increase this risk. However, they find neither a direct effect of droughts nor an effect conditioned by political rights or political exclusion in the affected areas.

The assessments of local effects and conditional effects in recent studies represent major advances in the debate. Yet there are still significant theoretical and empirical gaps. Most studies suggest that the most likely causal mechanisms from climate variability to conflict are mediated by the local economic impact of climate variability. However, when modeling this relationship, most studies have still mainly looked for direct correlations on an aggregate level. In order to assess the link between climate variability and conflict, we need to theorize upon, and empirically assess, under what circumstances droughts most likely translate into economic grievances and income shocks for affected populations. In particular, the question of how vulnerability and coping capacities shape the impact of drought and related disasters has been only insufficiently reflected in empirical studies on the effect of climate variability and conflict so far.

In addition, there are still few empirical cross-national studies at the subnational level that provide a more adequate match to the proposed local level mechanisms at work and that are able to assess more specifically the strength of the proposed linkages. Below I outline my theoretical framework, drawing both on the literature on participation in civil conflict and the literature on disaster risk reduction.

Theoretical framework: the local effect of droughts on civil conflict violence

Droughts increase the scarcity of resources that are vital for income and food provision. Rainfall shortages diminish fresh-water supply, the availability of arable land and agricultural productivity. It is unlikely that resulting economic hardship is a sufficient or necessary cause for a rebellion (Homer-Dixon, 1999). However, as will be argued in the following, it can add to pre-existing grievances thereby making civil conflict more likely, as well as provide incentives for affected individuals to join or support rebellion.

Drought may increase grievances against the state and create a fertile ground for the onset of insurgencies, as argued by Homer-Dixon (1999). Where individual economic hardships coincide with other ethnic, class or religious cleavages in society, they may translate into perceptions of relative deprivation felt by a societal group. This means that a group perceives a gap between actual economic achievements and what it perceives to be the deserved level (Homer-Dixon, 1999). If economic deprivation is blamed on the government, this may translate into an increased propensity to engage in violence against the state. An example of these dynamics is the rebellion in Peru. A crisis in subsistence in the early 1980s led to increased support for the leftist Shining Path rebels from among the peasantry (McClintock, 1984). The subsistence crisis was aggravated by natural disasters including drought and floods (McClintock, 1984). The Shining Path rebels blamed the government for the failure to provide access to food, health care and education and made promises about how it would improve lives. In accordance with relative-deprivation theories, support for the Shining Path rebels was highest in the rural departments with the lowest living standards (Weinstein, 2007).

Moreover, inter-communal or personal tensions resulting from drought may indirectly feed civil conflict violence. As Kalyvas (2003) argues, much of the violence observed in civil wars is fueled by local tensions and communal rivalry rather than being driven by a conflict's main cleavage. Individual and local actors take advantage of the war to settle conflicts that have little bearing on the goal of the belligerents. Thus, where a drought fuels such interpersonal or communal tensions, this may lead local actors to settle these conflicts in the context of civil conflict. For example, in the conflict in Darfur, Sudan, which started in 2003, Arab pro-government militias and rebel groups aligned along the same communal lines as in the communal fighting over land and water resources before the start of the civil war. These communal conflicts were in part caused by sustained drought (Brosché & Rothbart, 2013). In sum, drought may add to grievances that motivate actors to take up arms against the government or rival groups.

Largely independent of the aim and issues in fighting, the adverse economic impact of drought may also help to overcome the collective action problem of rebellion. Individual costs and risks associated with fighting a war are high. Therefore, mobilization that relies on a distant public good arising from winning a rebellion is difficult (Olson, 1965). Building on this argument, many have asserted that individual participation in fighting a war is a more attractive option when opportunity costs are reduced. In particular, nascent rebel groups find it easier to mobilize followers that lack outside economic alternatives (Collier & Hoeffler, 2004; Dube & Vargas, 2013; Fjelde, 2014). As Kalyvas (2006) emphasizes, economic considerations and questions of survival even become more important than political preferences in many cases. For example, in Spain, the Anti-Franco guerrillas in the 1940s dealt with peasants who favored whatever side was in control. Access to food was more important than a fight for their freedom (Kalyvas, 2006). Similarly, in the civil war in Sierra Leone, poor peasants were more likely to join both rebellion and counter-rebellion groups (Humphreys & Weinstein, 2008).

Where drought leads to food shortages and falling incomes, joining a rebel group is thus relatively more attractive. For example, rainfall shortages were associated with a higher rate of rebel recruitment in a survey of villages in Burundi (Nillesen & Verwimp, 2009). In Northern Ethiopia in the 1980s, the ranks of the leftist TPLF rebels swelled in unprecedented numbers during famine caused by drought (De Waal, 1991). In the latter case, government neglect of the plight of the Tigrayan population further motivated locals to join the rebellion against the state (De Waal, 1991). Thus, low opportunity costs and anti-government political preferences concurred.

Joining or supporting insurgency or counter-insurgency in a situation of economic hardships caused by drought comes with several benefits. Rebels typically use economic selective incentives in order to motivate followers. Besides political indoctrination, coercion and the use of ethnic vocabularies, rebel groups depend on a minimum of pecuniary rewards – if not wages, then at least food (Gates, 2002; Herbst, 2000). Thus, armed groups can provide alternative sources of income and sustenance. Collaboration and support of rebel groups is also more attractive for drought-affected civilians. Armed groups hamper regular economic activities by controlling access to infrastructure and markets and by restricting population movements (Justino, 2009). Collaboration with the insurgents is often rewarded with land, taxes and higher prices for produce, among other things (Kalyvas, 2006). Not only rebel groups, but also governments may use material benefits beyond wages in mobilizing counter-insurgency militias. For example, the Sudanese government promised land to the members of the Arab militia as a reward for fighting the Darfur rebellion (Brosché & Rothbart, 2013). Thus, for individuals who are impoverished due to drought, supporting a rebellion or counter-rebellion offers material benefits.

Both grievance-based explanations and rational-actor explanations of conflict have common empirical implications and may add up. *All else being equal*, a drought that decreases the supply of income and food makes people more likely to engage in civil conflict violence. These linkages between drought and conflict mainly rely on the adverse economic impact of droughts. Importantly, this has implications for the empirical expectations we should have for the conditions under which drought impacts conflict. The economic effects of drought are a function of the characteristics of the hazard (frequency, magnitude, duration) and the vulnerability and coping capacity of the affected (Kallis, 2008). Below, I identify two conditions that increase drought impact that have hitherto largely been neglected in the empirical study of climate variability and conflict: the duration of exposure to droughts, and the vulnerability of local agricultural production patterns to drought. I elaborate on these in turn.

Sustained droughts and reliance on rainfed agriculture increase vulnerability

Households in drought-prone areas develop strategies to both prepare for, and cope with, droughts. For example, farming households make use of diversification, migration, non-farm work and social support networks for coping with drought (Gray & Mueller, 2012; Roncoli, Ingram, & Kirshen, 2001).

However, although there may be long-held successful adaptive practices to normal climatic variation, they often fail in longer, repetitive droughts (Kallis, 2008). As Sabates-Wheeler et al., (2008) describe, households typically begin with low-cost, easily reversible strategies, such as mild rationing. Thereafter follow strategies that entail more costs, such as selling breeding livestock. These are not easily reversed. Once these strategies are exhausted as drought persists, households are forced to sell their key productive assets (such as farmland). In addition, the exposure to drought of entire communities in the same area diminishes the individual coping options available. For example, after a large-scale drought, employment opportunities in nearby areas are often reduced (Gray & Mueller, 2012).

This line of reasoning points not only to a disproportionate impact of prolonged drought, but also to repeated drought events adding up cumulatively. Losing productive assets has a long-term potentially irreversible impact and also leaves individuals more vulnerable to future shocks (Sabates-Wheeler et al. 2008). When key productive assets are lost, even a period of normal rainy seasons may not suffice for recovery. For example, in Ethiopia, even six years after the 1983–1985 droughts, when a large number of animals had been sold or died, the lack of plow oxen represented the single most severe constraint on rural production and made people vulnerable to famine (De Waal, 1991). Ethnographic research in Burkina Faso showed how most farming households after the 1997 drought entered the new farming season not only with a depleted financial base but also a reduced workforce, as young men were sent into migration to Côte d'Ivoire. Therefore, their ability to manage risk was reduced (Roncoli et al., 2001). Based on a global country level analysis, Dell, Jones, and Olken (2012) also provide evidence for the persistence of a negative effect of high temperature on economic growth. They show that, rather than a level effect, which is reversed with a return to normal climatic conditions, temperature has a negative growth effect that persists in the medium term.

In sum, taking into account decreasing coping capacities, we should expect sustained or repeated shortages in rainfall to have the most severe impact on livelihoods and income and, thus, indirectly, the decision to participate in violence.

This discussion leads to the first hypothesis.

H1. Sustained droughts increase the risk of civil conflict violence.

The effect of drought is in part determined by the duration and severity of physical exposure as argued above. However, also the pre-existing vulnerability, i.e. the capacity to anticipate, manage and recover from environmental hazards, determines the impact on livelihoods (Kallis, 2008; Sabates-Wheeler et al., 2008). Thus, exposure to drought of the same absolute magnitude is likely to have different impacts depending on the vulnerability of the region hit.

Vulnerability to drought is determined by a number of factors: However, arguably the most important factor is the degree of dependence on rainfall for food and income. In general, the largest and most immediate impact of droughts on food provision and income can be expected in the agricultural sector because of the reliance of this sector on surface and subsurface water supplies (Handmer et al., 2012). Droughts lead to declining crop yields and erode farming livelihoods (Sissoko, Keulen, Verhagen, Tekken, & Battaglini, 2011).

Rural areas with rainfed croplands are particularly sensitive to drought (Cooper et al., 2008). In these areas, there is no irrigation available that could cushion the effect of drought. In Sub-Saharan Africa, areas with rainfed agriculture are dominated by smallholder subsistence farming, in which households focus on growing enough food to feed themselves and have little adaptive capacities (Müller, Cramer, Hare, & Lotze-Campen, 2011). Because of their vulnerability, areas depending on rainfed agriculture are likely to be the most immediately and hardest hit by drought.

This leads to the second hypothesis.

H2. Regions with rainfed agriculture have a higher risk of civil conflict violence following droughts than other regions.

Data and research design

This study suggests that drought increases the local risk of civil conflict violence. In particular, the risk should be more pronounced after a sustained period of drought exposure and when individuals rely on rainfed cropland for income and food provision. Under these circumstances affected individuals are more likely to join and support rebellion in order to redress economic grievances or simply to obtain food and income.

The main units of analysis are annual observations of grid cells of 0.5 x 0.5 decimal degrees. The dataset covers the time period 1989 to 2008 in Sub-Saharan Africa. The size of the cells corresponds to roughly 55 $\times$ 55 km at the equator. The grid structure is taken from the PRIO-GRID dataset (Tollefsen, Strand, & Buhaug, 2012). The temporal aggregation into annual observations enables me to distinguish drought effects on conflicts from seasonal variations that affect the logistics of fighting as, for example, roads become more or less accessible (Carter & Veale, 2013).

The spatial resolution seems suitable from a theoretical and technical perspective. From a theoretical point of view, the location of the structures and events motivating individuals and the location of the fighting are often close to each other in spatial terms. The bulk of rebel fighters in civil wars is commonly native to the local areas they operate in (Kalyvas, 2006). Contemporary armed conflicts are usually confined to particular subnational hot spots (Buhaug & Gates, 2002; Schutte & Weidmann, 2011). Also agricultural patterns and drought exposure vary largely within a country. There are therefore good reasons to assume that individuals motivated by drought often fight relatively close to where they live. Nevertheless, the specific spatial resolution when relying on artificial grid structures remains somewhat arbitrary. Therefore, as an additional robustness check, annual observations of 1x1 decimal degrees are used (see Online Appendix).

From a technical point of view, 0.5 $\times$ 0.5 decimal degrees is the minimum recommended size of the grid cell. At this spatial resolution, conflict events data based on public sources present a fair representation of the location of the fighting (Weidmann, 2014). Moreover, at this spatial resolution, even smaller countries are represented by multiple grid-cells (Tollefsen et al., 2012).

Dependent variable: civil conflict incidence

The hypotheses concern the locations of fighting in civil conflict, synonymously referred to as intrastate armed conflict or rebellion, which is defined as a contested incompatibility that concerns government or territory or both where the use of armed force between the government and an internal opposition group results in at least 25 battle-related deaths in a calendar year (Gleditsch et al., 2002). The data for the dependent variable is taken from a new georeferenced event dataset collected by the Uppsala Conflict Data Program (UCDP GED version 1.5) (Sundberg & Melander, 2013). A conflict enters the UCDP GED once it results in 25 recorded battle-related deaths in a year. From that year on, battle events in the conflict that result in at least one fatality are given a geo-spatial reference including during years with fewer than 25 fatalities (Sundberg & Melander, 2013). The data is available from 1989 and onwards. Based on the data described above, all events from intrastate armed conflicts in the period 1989 to 2008 are selected. The dependent variable *conflict incidence* takes the value of 1 if there is at least one conflict event in an intrastate armed conflict resulting in at least one battle-related death occurring in a grid cell that year, and 0 otherwise. I prefer the binary indicators of conflict incidence as the division into events in UCDP GED is bound to be somewhat arbitrary and likely to be subject to reporting biases. Information that there was fighting in an area is more reliable than information on intensity (Weidmann, 2014). I use alternative specifications of the dependent variable in the Online Appendix.

Conflict incidences are noted in 2,624 (1.57%) of the annual observations of grid cells. The number of cells in conflict varies over time, but never exceeds 2.5% of the cells in a year. Most cell/year observations indicating incidences of civil conflict violence are found in Angola (572) followed by Ethiopia (375) and Sudan (362).

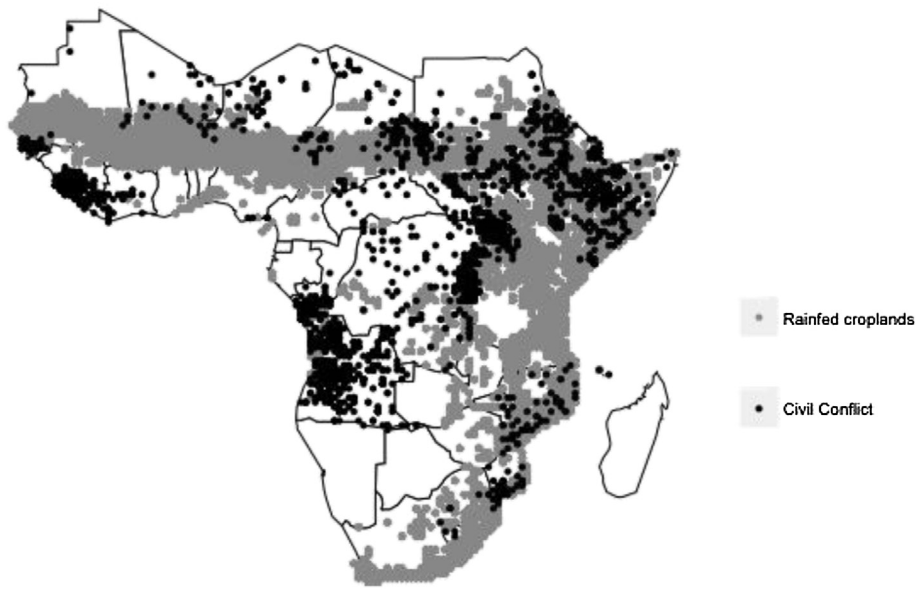

Fig. 1. The map displays the location of 0.5 x 0.5 grid cell observations in the dataset that contain any rainfed cropland based on information from the Globcover Dataset in grey (Bontemps, Defourny, & Van Bogeart, 2009). It shows in black the location of civil conflict in the period 1989–2008 from the UCDP GED (Sundberg & Melander, 2013).

These countries have the most sustained conflicts with the largest geographical extension in the period studied (see Fig. 1).

Independent variables: drought, sustained drought and rainfed agriculture

The theoretical framework suggests that droughts affect the local risk of civil conflict violence depending on their duration and on the agricultural production patterns of affected regions. There is no universally recognized definition of drought and its severity, and the range of definitions used reflects different meteorological and socio-economic concerns (Smucker, 2012). The disadvantage of socio-economic data on droughts is that it may be affected by ongoing conflict. For example, economic and human losses due to droughts are likely to be higher in conflict zones where access for disaster relief operations is more limited. Therefore, I choose to focus on meteorological droughts, i.e. the deficiency of precipitation for an extended period of time (Smucker, 2012).

Indicators based on the annual precipitation level potentially mask intra-annual drought conditions that are crucial for agricultural production. Instead, I employ an intra-annual drought measure based on the Standardized Precipitation Index (SPI6) (McKee, Doesken, & Kleist, 1993). The SPI6 is constructed as a single numeric value, which can be compared across regions with different climates. This measure is widely used and has proven suitable in the detection of drought conditions in Africa also compared to other drought indicators (Ntale & Gan, 2003). For each month, the SPI6 measures how much of the observed cumulative precipitation during the six preceding months departs from the long-term mean of that six-month period.[2] The deviation measures are standardized so that SPI6 estimates below 1 indicate near normal or wetter rainfall; 1 to 1.49 indicate moderately dry conditions; 1.5 to 1.99 indicate severely dry; and values in excess of 2 standard deviations indicate extremely dry conditions (McKee et al., 1993).

For the main operationalization of the variable *drought*, I rely on the annualized SPI6 index following the example of Theisen et al. (2011). As the SPI6 variable has an ordinal rather than interval scale, I employ a dummy-coded variant of the SPI6 taking the value 1 if two conditions are met (and 0 otherwise): there are at least three consecutive months with (at least) moderate drought in the given grid cell during the year; and a severe drought for at least two consecutive months. This corresponds to the maximum of 2.5 on the scale of the annualized SPI6. This variable is thus capturing considerable precipitation deficit. The measure is taken from the PRIO-GRID dataset (Tollefsen et al., 2012). It is based on monthly precipitation data provided by the Global Precipitation Climatology Centre (Rudolf, Becker, Meyer-Christoffer, & Ziese, 2010).

The first hypothesis suggests that the conflict-inducing effect of drought should be amplified by longer drought exposure. As discussed above, both a long duration of drought and repetitive drought events are likely to increase the impact of drought. To capture these expectations, sustained droughts are measured in several alternative specifications.

I create the variable *continuous droughtyears* summing up the number of consecutive years of drought according to the operationalization given above. Accordingly, for example, a drought in the two preceding years will be indicated by the continuous droughtyears variable as 2. This variable thus reflects the expectation that drought has a larger impact when it is present over a prolonged period. In about 3,200 observations, we see droughts that last 2–8 years. As the drought variable is based on precipitation data that extends to the 1950s, early years in the dataset have the same chance to see a prolonged drought by the design of the variable. Comparing selected cases in the data with socio-economic data on droughts, this variable captures, for example, the sustained drought in starting in the late 1990s in Ethiopia, which led to a severe food crisis (Maxwell, 2002).

Yet droughts can also have a cumulative economic impact beyond the period in which they are present, when they lead to a loss in productive assets. In order to capture the effects of sustained droughts that are interrupted in time by normal years, the variable *sum droughtyears* counts the total number of years seeing drought in the past five years. The sustained drought variables thus also capture spikes in the drought frequency in the 1980s, when for example the Sahel, with regional variations, saw an extended drought period (Dai et al., 2004). The data is entered in the models at t−1 based on the expectation that the economic effect of drought is felt with a temporal lag when stocks are emptied. This also ensures the right temporal order of the independent and dependent variable.

The second hypothesis suggests a stronger effect of drought in regions with rainfed croplands than in other regions. The variable *rainfed* is based on satellite-based information on the land cover from the Globcover project (Bontemps, Defourny, & Van Bogeart, 2009). The Globcover project distinguishes between over 20 land classes, distinguishing the type of vegetation from water bodies and urban areas. Based on information provided in this dataset, the main measure is coded 1 if at least 0.5% of the area of the 0.5 $\times$ 0.5 decimal degree grid cell is covered with rainfed cropland, and 0 otherwise (based on land class 14 in the Globcover data). Rainfed cropland includes rainfed shrub crops, rainfed tree crops and rainfed herbaceous crops, but excludes irrigated and post-flooding crop cultivation, which are likely to be less sensitive to precipitation loss (Bontemps et al., 2009). The Globcover variables are available for 2009 only. The variable is entered into the dataset as a time-invariant measure. Croplands are estimated to follow an expanding trend, but annual rates of change are relatively small (Ramankutty, Foley, & Olejniczak, 2002). This variable should thus be suitable for capturing general spatial patterns in crop cultivation. The variable is taken from the PRIO-GRID dataset (Tollefsen et al., 2012). About a third of the cells contain some rainfed agriculture (see Fig. 1), 16 percent of the grid cells are covered with rainfed agriculture by more than 0.5% and are thus coded as 1.

Statistical model and control variables

The aim of the statistical models is to estimate the causal effect of sustained drought on conflict. Meteorological drought can be considered exogenous to human behavior in general. Therefore, the need to control for potentially confounding variables is minimized. Indeed, rainfall has often been used as an instrumental variable for economic growth (Kim, 2014; Miguel et al., 2004). However, the independent and dependent variable of this study could be spuriously linked by temporal and spatial patterns. In particular, some regions have a more variable climate than others and therefore a higher risk of experiencing sustained droughts. If these regions also happen to observe a higher risk of conflict, an observed correlation could be spurious. Addressing this concern, my main models include grid-cell fixed effects in order to take into account time-invariant heterogeneity between units. Moreover, we might potentially observe a trend in drought that coincides with other correlates of conflict and therefore could lead to spurious correlations (Hsiang & Burke, 2013). The main models include year dummies to account for these time trends. However, the inclusion of these time controls may also bias down the effect of drought. Global climatic shifts like the El Niño phenomenon increase the risk of drought in larger areas. For example, in Southern Africa droughts often occur in the rainy season after the onset of an El Niño event (Thompson et al., 2003). I therefore test whether results are robust to the inclusion and exclusion of time controls. The main models use logistic regression, as the dependent variable is dichotomous (Beck, 2011).

There are reasons both to include and to leave out additional control variables, so I show models with and without controls to test the robustness of the results. On the one hand, an argument against including variables such as poverty and population is that the study aims to gauge the total effect of drought, which is likely to be mediated by these other variables. Sustained drought is likely to affect economic activity and population through migration patterns (Gray & Mueller, 2012). These are in turn linked to conflict and, thus, could mediate the local effect of drought on conflict. Including these variables in a statistical model may therefore lead us to conclude, based on the drought coefficient in a statistical model, that the association between drought and conflict is weaker than it really is. On the other hand, while the occurrence of drought is exogenous to human activity, agricultural patterns are not, but are correlated with other socio-economic factors (Morton, 2007). Therefore, controlling for alternative factors clustered with agricultural patterns is useful in order to test whether rainfed agriculture conditions the effect of drought on conflict.

In a second set of models, I therefore account for characteristics of the grid cell that affect the likelihood of civil conflict violence and could also be linked to rainfed agriculture. I include a control for economic development within the cell, *GCPpc*, based on the G-ECON data, which calculates the gross cell product, the local equivalent of the gross domestic product (Nordhaus, 2006). Low levels of absolute income predict the occurrence of political violence (Hegre, Østby, & Raleigh, 2009). Previous research also finds a robust, positive relationship between population and political violence in the context of civil wars (Raleigh & Hegre, 2009). I include a control for *Population* in the grid cell (CIESIN & CIAT 2005). Both the GCPpc and the population variables are taken from the PRIO-GRID dataset (Tollefsen et al., 2012). Both variables are available for every fifth year starting in 1990 and values for missing years have been interpolated. Both variables are logged to reduce the influence of extreme values. In addition, I include data on ethnic exclusion, which is linked to conflict (Theisen et al. 2011) and could be linked to agricultural livelihoods. The variable *Exclusion* indicates whether the majority ethnic group settling in the grid cell held a position in the government in a given year. It is coded 1 if local ethnic groups were excluded, and 0 if they had a government position in a given year. This variable is based on the geoEPR dataset on the settlement patterns of ethnic groups (Wucherpfennig, Weidmann, Girardin, Cederman, & Wimmer, 2011). This data is used together with the EPR 3 dataset, providing time-variant information on the political status of ethnic groups (Wimmer, Cederman, & Min, 2009).

Conflict observations cluster in space and in time. A *spatial-temporal lag* of the conflict variable is included in some models in order to control for dependence in conflict occurrence in both time and space. This variable indicates whether there was ongoing conflict in the same, the first-order or the second-order neighborhood of the cell in the previous year. This corresponds to a buffer around the borders of a cell of at least 110 km in each direction. It thus ensures that diffusion processes from neighboring areas to a cell and continuous fighting in the same area are accounted for in the statistical model (Ward & Gleditsch, 2008).

Results and analysis

In this section, I present the results from multiple logistic regression analyses of the association between droughts and the occurrence of civil conflict at the local level. First, I focus on sustained droughts. I start with descriptive patterns found in the data and find preliminary evidence for the suggested relationship. Fig. 2 shows the average level of conflict at different values of the main sustained drought variables. From 1.3% of cells seeing conflict when there has been no drought at all, the average level of conflict rises to 4.8% after 3 *continuous droughtyears*. For the *sum of droughtyears*, the average level of conflict rises to 3% after three years. Very few observations see more than 3 years of drought. Those that do have again a lower conflict risk on average.

I move on to fixed effects logistic regression models that allow me to take into account time-invariant heterogeneity among the units and time trends. In Table 1 I evaluate the first hypothesis that sustained drought increases the local risk of conflict. For comparison with previous research, I start by estimating whether there was

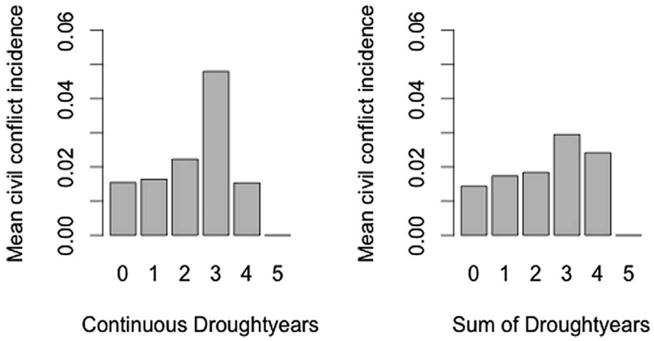

Fig. 2. The figure shows the average of civil conflict for different values on the two specifications of the sustained drought variable based on the full sample, Sub-Saharan Africa 1989–2008.

a drought in the previous year or not (model 1). In line with earlier research, there is no significant relationship between drought in the previous year and conflict (cf. O'Loughlin et al., 2012). Moving on to the effect of sustained drought, models 2 to 4 present alternative specifications of the sustained drought variables in statistical models. The results overall provide some support for the suggested relationship. The coefficient for the *continuous droughtyears* variable is positive, but only significant at the 90%-level controlling for both location and time fixed effects (model 2). It is highly significant when only either one of the fixed effects is included (models not reported). When using the *sum of droughtyears* specification for sustained drought instead, the coefficient is positive and significant at the 95%-level (model 3). The relationship between *sum of droughtyears* and conflict is also robust to the inclusion of contextual variables (model 4). However, when modeled without unit fixed effects and with contextual variables, the coefficient is positive but below statistical significance (model not reported).

One explanation for the sensitivity of results to leaving out fixed effects is that without fixed effects the logistic regression model takes into account cross-unit variations in addition to over time variation. Therefore, differences between these models point to the existence of conditional effects. Droughts likely act as additional stressors that make a region more likely to see conflict in some circumstances, but not in others. For example, city centers or inhabitable deserts might be exposed to rainfall shortages, but this is unlikely to increase conflict risk.

As suggested in Hypothesis 2, one potential conditioning variable is rainfed agriculture, which is particularly sensitive to rainfall shortages. Next, I evaluate whether the risk of civil conflict violence following drought is higher in areas dominated by rainfed cropland. Models 5 to 10 provide a first assessment using split samples of areas based on the rainfed cropland variable. Split samples of regions with rainfed agriculture all show a significant relationship between different measures of drought and conflict (models 5–7). Notably, for regions with rainfed croplands, the variable drought t−1 is positive and significant at the 95%-level (model 5). The two alternative operationalizations of sustained drought (models 6 and 7) are positive and significant at the 95%-level or higher. Thus, not only after sustained droughts, but also after shorter droughts, there is an increase in conflict risk in regions with rainfed agriculture. In contrast, outside of these areas (models 8–10), there is no consistent association between drought and conflict. In model 8, the indicator for drought t−1 is negative while not significant. Moving on to sustained droughts only one of the variables is positive and significant (models 10). (Table 2).

In sum, the above results of the split samples lend support to the notion that the conflict-inducing effect of droughts is mostly seen in regions where the patterns of agricultural production render the local population particularly sensitive to shortages in precipitation. However, the regressions on split samples do not allow me to determine whether the conflict-inducing risk of drought is conditional on the existence of rainfed croplands, or whether patterns of physical vulnerability to drought simply tend to cluster geographically with rainfed agriculture, and produce regions at a high risk of violence. In particular, while drought can be considered to be exogenous to human activity, agricultural patterns are not. The patterns discovered could thus also be due to other systematic differences between rainfed croplands and other areas, for example regarding population, economic development and the political status of groups.

Next, I examine whether there is a significant difference between the effect of drought in and outside of areas with rainfed agriculture. Accordingly, I introduce interaction terms between the variables for drought and rainfed agriculture in the statistical model. I also introduce control variables that could explain the differences in the results of the split samples. As the variable rainfed agriculture is time-invariant, I do not include fixed effects to be able to gauge the effect of this variable.

With the introduction of interaction terms, constituent terms can no longer be interpreted as marginal effects, but as conditional marginal effects when the value of the other component variable is zero. In order to facilitate interpretation of the table, I recode the modifying dummy variable *rainfed* by subtracting 1. The constituent term of the drought variables denotes conditional marginal effects in the presence of rainfed croplands in Table 3.

In line with Hypothesis 2, in all the specifications of the model, the coefficients of the constituent terms for the drought variables are positive and significant. Thus, they corroborate the results of the split sample models. After one drought in the previous year (model 11), as well as after sustained periods of drought (models 12 and 13), agricultural regions see a higher risk of civil conflict violence, controlling for variations in population, economic development and ethnic exclusion across the full sample of grid cells.

Next, I turn to the interaction with rainfed agriculture, in order to answer the question whether there is a statistically significant difference between the drought effect in areas with rainfed agriculture and other regions. In non-linear models, the significance of the interaction cannot be tested with a simple *t*-test on the interaction term (Berry, DeMeritt, & Esarey, 2010). I follow the recommendations of Berry et al. (2010) to evaluate the presence of interaction effects by using the CLARIFY software to calculate estimated effects of a change in the drought measures setting the rainfed cropland variable to 0 and 1 respectively with all other

Table 1
Results of fixed effects logistic models of sustained drought and civil conflict.

	Model 1	Model 2	Model 3	Model 4
Drought $_{t-1}$	0.0356 (0.0807)			
Continuous droughtyears		0.0856* (0.0512)		
Sum droughtyears			0.108** (0.0332)	0.132*** (0.0383)
Population (ln) $_{t-1}$				0.0951 (0.475)
GCP pc (ln) $_{t-1}$				−0.0739 (0.175)
Exclusion$_{t-1}$				0.239** (0.120)
Temp-spat. lag conflict				1.644*** (0.0661)
Observations	20,260	20,260	20,260	17,024

Standard errors in parentheses. *$p < 0.10$, **$p < 0.05$, ***$p < 0.001$. All models include unit and year fixed effects.

Table 2
Results of fixed effects logistic regression based on rainfed croplands, split samples.

	Model 5 rainfed = 1	Model 6 rainfed = 1	Model 7 rainfed = 1	Model 8 rainfed = 0	Model 9 rainfed = 0	Model 10 rainfed = 0
Drought $_{t-1}$	0.473**			−0.0664		
	(0.169)			(0.0930)		
Continuous droughtyears		0.236**			0.0331	
		(0.0934)			(0.0615)	
Sum droughtyears			0.224***			0.0829**
			(0.0671)			(0.0386)
Observations	4,680	4,680	4,680	15,580	15,580	15,580

Standard errors in parentheses. *$p < 0.10$, **$p < 0.05$, ***$p < 0.001$. All models include unit and year fixed effects.

variables held at their mean (King, Wittenberg, & Tomz, 2003). Fig. 3 displays calculated changes in relative risks associated with a simulated change in the drought variables based on the models in Table 3. Outside areas with rainfed agriculture, the estimated risk from drought compared to a situation without drought always includes 1. Thus, there is no significant change in risk associated with drought in these areas. In contrast, in rainfed croplands, the estimated mean change in relative conflict risk for a shift on the drought t−1 variable from 0 to 1 is 60%. The estimated mean effect increases up to the double risk for areas that have seen three years of drought compared to a scenario of no drought.

Second differences for the changes in the drought variables in areas with and without rainfed agriculture are all significant (not reported). Thus, there is a statically significant difference between areas with rainfed croplands and other regions in line with the theoretical expectations. In sum, this result lends support to the argument that regions with rainfed croplands are particularly vulnerable to deficiencies in precipitation and even shorter periods of drought have a substantive impact on conflict risk. Similarly, for the sustained droughts, we observe the most robust effect in regions with rainfed croplands.

The control variables behave largely as expected. The temporal spatial lag of the civil conflict variable is always positive, large in size and highly significant as expected, implying that conflict events cluster in time and space. The variable measuring population is positive and significant in all models, suggesting that more populous regions are more likely to see armed conflict. Political exclusion is associated with a higher risk of civil conflict violence. The result for the economic development variable is less consistent. A reason for this result could be the diverging effect of income at the subnational level, where both especially rich and especially poor subnational regions are suggested as seeing a higher risk of conflict (Buhaug, Gleditsch, Holtermann, Østby, & Tollefsen, 2011).

Table 3
Results of logistic regression of models of interaction of drought and rainfed croplands.

	Model 11	Model 12	Model 13
Drought$_{t-1}$	0.514***		
	(0.145)		
Drought$_{t-1}$*norainfed	−0.542**		
	(0.169)		
Continuous droughtyears		0.234**	
		(0.0840)	
Continuous droughtyears*no rainfed		−0.233**	
		(0.101)	
Sum droughtyears			0.239**
			(0.0775)
Sum droughtyears*no rainfed			−0.223**
			(0.0887)
norainfed	0.163	0.142	0.226*
	(0.115)	(0.115)	(0.121)
Population (ln) $_{t-1}$	0.362***	0.362***	0.361***
	(0.0311)	(0.0311)	(0.0310)
GCP pc (ln) $_{t-1}$	0.0776*	0.0781*	0.0821*
	(0.0435)	(0.0436)	(0.0437)
Exclusion$_{t-1}$	0.593***	0.592***	0.582***
	(0.0931)	(0.0930)	(0.0924)
Temp-spat.lag Conflict	2.846***	2.844***	2.849***
	(0.0658)	(0.0657)	(0.0659)
Constant	−10.24***	−8.906***	−10.33***
	(0.530)	(0.499)	(0.533)
Observations	151,863	151,863	151,863

*$p < 0.10$, **$p < 0.05$, ***$p < 0.001$ Standard errors clustered by grid cell in parentheses. The results remain substantially unchanged with year fixed effects included.

Robustness checks

A number of additional robustness tests have been performed on the main results: (1) A change in the unit of analysis to 1 × 1 degree grid cells, (2) alternative measures of rainfed agriculture, (3) changes in the operationalization of the dependent variable, and (4) changes in the drought variable. The results are reported in the Online Appendix. Below, I elaborate on each of these in turn.

First, an issue of concern in the analysis of grid cells is the so-called Modifiable Areal Unit Problem (MAUP). The imposition of artificial units on continuous geographical areas generates artificial spatial patterns. This may lead the same raw data to yield different results when aggregated to different geographical units (Openshaw, 1984). As an alternative set-up I use a grid structure with a 1 × 1 degree cell size, by collapsing four of the original units of analysis into one new unit. The results remain substantially unchanged in the preferred specification with fixed effects controlling for unobserved heterogeneity between units. The interaction with rainfed agriculture is less pronounced, though. (Table A2).

Second, I use alternative specifications of the rainfed variable coding all cells containing *some* rainfed agriculture, irrespective of

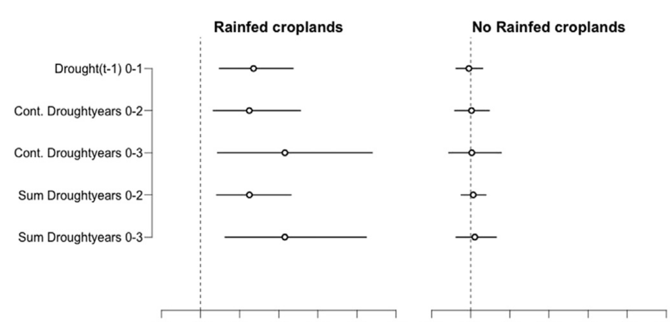

Fig. 3. The figure shows estimated changes in the relative risks for civil conflict incidence when the value of the drought measure shifts from 0 to up to 3 (the value indicated next to the variable name) with the rainfed cropland variable set to 0 and 1 respectively. Estimates are based on CLARIFY simulations of models in Table 3 based on the full sample with all control variables set at their mean value. The mean point estimate is marked with a dot, and 95% confidence bands with lines. Where the confidence intervals include 1, there is no statistically significant difference between situations of drought compared to no drought. The value 2, for example, indicates a doubled risk. Values below 1 indicate a reduced risk.

the size area, as 1, and 0 otherwise. The results remain substantially unchanged. As a second modification, I distinguish between cells containing any cropland (irrigated, rainfed or mosaic cropland, where rainfed cropland is mixed with other vegetation) or none. The association between drought$_{t-1}$ and conflict in all kinds of croplands is not significant any more, while it is substantially unchanged for sustained droughts compared to the main model (Table A3). This result is in line with the expectation that rainfed croplands are particularly vulnerable compared also to other agricultural production patterns (Cooper et al., 2008).

Third, a potentially serious concern for the robustness of the results is the influence of temporal autocorrelation. As we do not know the source of correlation, this issue is addressed in the main models by assuring that results hold for the inclusion of spatial-temporal lags of the dependent variable and year dummies that control for e.g. global trends in commodity prices. To address this problem beyond these measures, I rerun the models with an alternative dependent variable where only the first year of fighting in a cell is coded (*Cell Onset)*. The variable is coded 1 if there was fighting after at least 2 years of peace in the grid cell and set to missing for subsequent years of fighting. The results are in line with the main results. (Table A4).

Finally, I alter the drought specification. In the main analysis, I focus on instances of severe drought. As alternative specification of sustained drought, I include also minor and moderate drought levels in the construction of the sustained drought variables, counting the number of years a region has seen any drought event. I do not find any significant relationships with conflict. In line with the theoretical framework, coping capacities may help individuals to adapt peacefully to a certain degree when the drought is not severe.

Discussion

Taken together, these results suggest that drought substantially increases the risk that a subnational region experiences civil conflict events in regions with rainfed croplands. There is also some support for the proposition that sustained droughts have an impact on conflict risk, a result not limited to rainfed croplands.

Do these results support the alarmist notion of "climate wars"? Not necessarily. Although drought is associated with an increased risk of civil conflict violence in agricultural areas in Africa, it should be noted that moderate or low levels of drought of any duration are not systematically linked to conflict. In addition, while rainfed croplands are one conditioning factor in the relationship between drought and war, there are likely other factors that determine what agricultural areas will see conflict.

In general, a closer look at the data reveals that drought seems mostly to add fuel to already existing conflicts and tensions in agricultural regions. In the data used in this study, the relationship between drought, rainfed agriculture and conflict is mainly found in regions with rainfed croplands located in Burundi 1995–2003, Ethiopia 1989–1991 and 1999–2004 as well as Sudan 1989–1991, 1997–2002. All of these countries saw recurring or ongoing civil conflict during these periods. Thus, there are tensions, grievances and at least a core of rebel fighters in these countries. At least some of the "fixed costs" of initiating war against the government have already been paid.

These illustrative cases point to a likely feedback loop between vulnerability to drought and conflict. Violent conflict undermines human security and the capacity of individuals, communities and states to cope with disasters like drought. War fragments rural markets as transportation networks cease to function, and financial institutions withdraw services (Wood, 2008). It also hinders effective disaster response by local and international humanitarian actors (Wisner, 2012). Warring actors may even purposely increase the suffering of populations affected by drought. For example, in Djibouti, the government imposed an embargo on the shipment of food and aid on the drought-hit rebel stronghold in the northern region (Reuters News, 1994). In sum, ongoing conflict and drought vulnerability may mutually reinforce each other.

Conclusion

Using novel geo-referenced event data on conflict matched with high-resolution drought data, this paper provides a comprehensive study on drought and sub-national variations in intrastate armed conflict in Sub-Saharan Africa, explicitly modeling the expectations that the impact of drought will be greater after a prolonged period of exposure and in regions with rainfed agriculture. The results suggest that drought substantially increases the risk that a subnational region with rainfed croplands will experience civil conflict events. There is also some support for the proposition that areas experiencing sustained droughts have a higher risk of conflict.

In the long term, the substantial significance of the findings of this paper hinges on future trends in climate change and, in particular, the future frequency of drought. However, if the link between drought and conflict is mediated by economic shocks in rainfed agriculture, as suggested in this paper, strengthening future coping capacities in the agricultural sector is even more important. It is estimated that overall yield losses will aggregate up to 22% across Sub-Saharan Africa by mid-century, with regional variations (Niang et al., 2014). Reducing agricultural vulnerability to drought is thus a "no regret strategy" that will have general benefits for rural development beyond potential security implications.

While the subnational research design of this study arguably provides a more credible research design for individual and group-level explanations of conflict than country-level data, it still can say little about causal mechanisms and micro-level conditional factors. Most of the empirical cases fitting the suggested pattern of drought, rainfed croplands and conflict are already ongoing, pointing to the interaction with other socio-political factors that together create a dangerous mix. Thus, there is a need for future research to further scrutinize possible conditional effects and causal mechanisms. For example, individual level characteristics such as education and economic status affect the vulnerability to disasters and also the propensity to partake in violent conflict. It is not well understood how micro-level economic factors in general influence the start of violent conflicts, and how those processes change and evolve throughout the conflict (Justino, 2009). Another underexplored field of study is how rebel groups and government manage drought during conflict. It should be a priority for future research to further disentangle micro-level processes shaping vulnerability to disaster and conflict behavior.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.polgeo.2014.10.003.

End notes

[1] Moreover, the causes and dynamics of diverse social phenomena like interpersonal conflict, communal violence and civil conflict differ. A claim of causal homogeneity is therefore more convincing when narrowing the focus to violence involving the same type of actors (Buhaug et al. 2014).

[2] In more detail, the SPI is calculated as follows. A long-term time series of precipitation accumulations over the time scale (here six months) are used to estimate a suitable probability density function. Next, the associated cumulative probability distribution is estimated. As a next step, it is transformed to a normal distribution. The resulting SPI can be interpreted as a probability using the standard normal distribution (i.e., for example, users can expect the SPI to be within two standard deviations about 95% of the time) (McKee et al. 1993).

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