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Conflict and its relationship to climate variability in Sub-Saharan Africa

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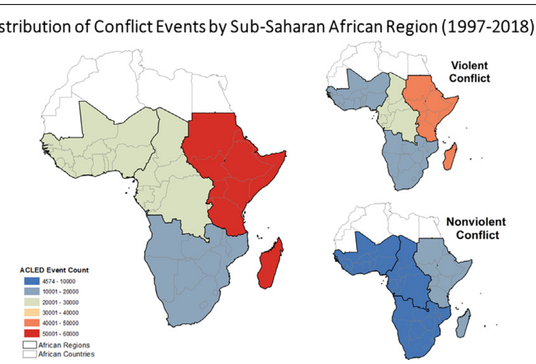
HIGHLIGHTS

- Regional differences in the likelihood of transitioning into conflict
- Seasonal specific linkages between rainfall and conflict
- Above average rain during the harvest season is more likely to result in conflict

GRAPHICAL ABSTRACT



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ABSTRACT

Deviations in rainfall duration and timing are expected to have wide-ranging impacts for people in affected areas. One of these impacts is the potential for increased levels of conflict and accordingly, researchers are examining the relationship between climate variability and conflict. Thus far, there is a lack of consensus on the direction of this relationship. We contribute to the climate variability and conflict literature by incorporating Markov transitional probabilities into panel logit models to analyze how monthly deviations in rainfall affect the likelihood that a grid cell transitions to an above average level of conflict in Sub-Saharan Africa. To control for differences in seasons across the continent, we model this relationship for each of the regions of Sub-Saharan Africa separately – East, Central, West, and Southern. We find significant seasonal and regional effects between rainfall and the probability that a grid cell transitions from a state of peace to a state of conflict. In particular, above average rainfall is associated with a higher likelihood of transitioning into conflict during the dry season. Further, each region has specific months—primarily those associated with prime crop harvest periods—where variations in rainfall significantly influence conflict. We also find regional variations in the linkage between rainfall and conflict type related to the types of conflict that predominate in particular regions of Sub- Saharan Africa. These findings are important for policymakers because they suggest additional law enforcement and/or peacekeeping resources may be needed in times of above average rainfall. Policies that provide financial support for farmers or other sectors, such as mining, that are impacted by rainfall patterns may also be a useful strategy for conflict mitigation.

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1. Introduction

Increased climate variability is expected to considerably impact global precipitation and temperature regimes (IPCC, 2018). Some parts of the world are projected to experience an increase in the frequency, intensity, and/or amount of precipitation while others are projected to experience an increase in the intensity or frequency of droughts (IPCC, 2018). These deviations in rainfall duration and timing are expected to have wide-ranging impacts on the people living in the affected areas. One of the possible effects of changes in rainfall is a change in the likelihood of human conflict (Hsiang et al., 2013; Burke et al., 2015a; Sakaguchi et al., 2017). There is a large and growing body of work exploring the linkage between rainfall and conflict with varied results (Buhaug et al., 2015; Hsiang et al., 2013; Kelley et al., 2015; Mach et al., 2019; O'Loughlin et al., 2012; Roche et al., 2020). Some studies find no linkage between rainfall and conflict (Buhaug et al., 2015; Witmer et al., 2017) while others find evidence of a linkage. However, there has not been a consensus thus far on the direction of this relationship. Some researchers find that less rainfall leads to conflict (Almer et al., 2017; Jones et al., 2017; Price and Elu, 2017), while others find that more rainfall leads to conflict (O'Loughlin et al., 2012; Salehyan and Hendrix, 2014; Theisen, 2012). In addition, some research finds that any deviation from the normal amount of rainfall leads to conflict (Harari and Ferrara, 2018; Papaioannou, 2016; Raleigh and Kniveton, 2012). Given the differing results in the literature, additional research on this topic is warranted.

In this paper, we contribute to the climate variability and conflict literature by using Markov transitional probabilities to examine how monthly deviations in rainfall affect the likelihood an area transitions to an above average level of conflict in Sub-Saharan Africa. This paper makes two contributions to the literature. First, we implement a previously unused analytical method for this type of analysis, Markov transitional probabilities, that provides new insights about the onset of conflict in relation to changing rainfall patterns. Specifically, the empirical results of Markov chains enable us to analyze the extent that rainfall patterns contribute to the transition from a state of peace to a state of conflict in the subsequent year. This is an important departure from prior empirical work that analyzes the incidence of conflict in a particular year (Fjelde and von Uexkull, 2012; Hendrix and Salehyan, 2012; Salehyan, 2014; von Uexkull, 2014). Second, we expand on prior studies (Harari and Ferrara, 2018; Miguel, 2005; O'Loughlin et al., 2012; Thiessen, 2011) by estimating separate models for the four regions of Sub-Saharan Africa. This provides region specific estimates of the linkage between rainfall and the onset of conflict that enable us to model variations in the dry and wet seasons across the continent. This approach captures nuances in these seasonal relationships that are important to identifying key months in each region when rainfall deviations are the most impactful. Stratifying by region and conflict type allows us to identify regions more prone to particular types of conflict than others.

We find evidence of conflict persistence; areas at peace tend to remain at peace while areas in conflict tend to remain in conflict. However, for grid cells that transition from peace to conflict, the transition exhibits notable seasonal effects. For example, in Southern Africa, we find that above average rainfall during the harvest increases the likelihood of transitioning into conflict. This may reflect the fact that excess rain during the harvest can be detrimental to crops. These findings are important for policymakers because they suggest additional law enforcement and/or peacekeeping resources may be needed in times of above average rainfall. However, it is important to note that due to regional differences in this link, tailored, place specific conflict mitigation and peacekeeping strategies are needed.

2. Prior investigations into the relationship between rainfall and conflict

Research on the impact of rainfall on conflict has generally reached one of four conclusions: 1. No linkage between rainfall and conflict (Buhaug et al., 2015; Witmer et al., 2017); 2. Less rain/drier conditions lead to more conflict (Almer et al., 2017; Jones et al., 2017; Price and Elu, 2017); 3. More rain/wetter conditions lead to more conflict (O'Loughlin et al., 2012; Salehyan and Hendrix, 2014; Theisen, 2012); 4. Any deviation in rainfall leads to more conflict (Harari and Ferrara, 2018; Papaioannou, 2016; Raleigh and Kniveton, 2012). We consider each of these literatures and the theories behind them below.

2.1. No relationship between rainfall and conflict

There are several explanations for studies that find no linkage between climate change and conflict. Some scholars suggest that the linkage between climate and conflict is highly contextual and operates through a variety of pathways (Burke et al., 2015b) including human health (Burke et al., 2015a) and food and water security (Ahmed et al., 2016). For example, studies have suggested that climate change may alter harvest patterns, which then impacts food security (Buhaug, 2016). Thus, it is the food security issue and not climate change which produces conflict. Another line of thinking argues that demand-side factors (e.g. population growth, increases in agricultural production, economic development) may be more important drivers of conflict than supply-side factors (e.g. climate) (Böhmelt et al., 2014). Other explanations for a lack of concrete evidence are the type of conflict considered (e.g. civil war, protests, armed conflict) and also the source of conflict data. For example, a study examining large-scale conflicts like civil war (Theisen et al., 2011) may find not a link with climatic factors, while studies considering smaller scale-conflicts like riots may find a linkage (Fjelde and von Uexkull, 2012).

2.2. Reductions in rainfall increase conflict

Some studies argue that there is a relationship between rainfall and conflict because of a scarcity issue; when water is not available people are more likely to engage in conflict (Burke et al., 2015b; Homer-Dixon, 1994; Hsiang et al., 2011, 2013). Almer et al. (2017) found that rioting increases in unusually dry conditions, particularly in areas where there is more competition for water. The findings of Eriksen and Lind (2009) are similar; fewer water resources create more conflict over water rights and access between farmers and herders. Couttenier and Soubeyran (2014) also found a positive effect of drought on the likelihood of civil war.

Another explanation for a negative relationship between rainfall and conflict is that it drives migration in order to obtain the necessary resources for survival (Reuveny, 2007; Kelley et al., 2015; Brzoska and Fröhlich, 2016; Burrows and Kinney, 2016). This migration could lead to an outbreak of violence by exacerbating existing ethnic or religious divides (Kelley et al., 2015). Other studies argue that if a decrease in rainfall reduces the profitability of an area, then the opportunity cost of conflict will decrease, thereby increasing the amount of conflict (Chassang and Miquel, 2009; Collier and Hoeffler, 1998). For example, if rainfall decreases and crop yields are reduced or crop failure ensues, farmers have less of an opportunity to profit through legal work. Therefore, because the opportunity cost diminishes, more individuals may engage in conflict.

Finally, less rainfall could affect local government finances. Specifically, a reduction in rainfall could strain government revenues through a reduction in the tax base as well as a simultaneous increase in the demand for services (Benson and Edward, 1998). Due to the reduction in revenues, the government may not be able to keep its citizens sufficiently satisfied and resist rebellions (Fearon and Laitin, 2003). Brückner and Ciccone (2011) found that droughts in Africa undermined the credibility and capability of autocratic states and increased the odds of a transition to a more democratic form of government.

2.3. Increases in rainfall increase conflict

There are arguments against the scarcity school of thought, however. Opponents suggest that reductions in rainfall reduces resources

(Collier and Hoeffler, 1998, 2005), which increases the amount of energy devoted to obtaining food and water to meet basic needs. The energy devoted to these efforts reduces the time that could be devoted to conflict, thereby decreasing the level of conflict (Theisen, 2012).

Alternatively, in times of increased rainfall, crop yields are plentiful and there are more resources to fight over (Klomp and Bulte, 2013; Witsenburg and Adano, 2009). Salehyan and Hendrix (2014) found that an abundance of water has a *positive* effect on the outbreak and sustainment of conflict, even after controlling for demographic characteristics such as the growth and level of GDP and population. The type of conflict in question may also matter. Large scale conflicts require the mobilization and availability of a significant number of resources. Therefore, large scale conflicts may be less likely in times of resource scarcity.

2.4. Deviations in rainfall increase conflict

Some studies have found a U-shaped relationship between rainfall and conflict (Hendrix and Salehyan, 2012; Papaioannou, 2016; Raleigh and Kniveton, 2012). These studies provide evidence that deviations from normal rainfall patterns produce conflict regardless of whether there is more or less rainfall than usual. For example, Papaioannou (2016) found conflict occurs in both wet and dry years but that conflict is more acute in wetter as opposed to drier years. They suggest that this pattern is related to two factors: timing of crop failure and the destruction of roads. Crop failure is more immediate in wet years, creating a quicker onset of conflict in response to lost resources. In addition, if road infrastructure is destroyed during a wet season with excess rainfall, then it is more difficult for authorities to travel to conflict areas. In dry periods, there may be a delayed onset of conflict because farmers are waiting for rain and the infrastructure is not affected immediately.

The type of conflict could also explain which type of deviation is more important. Hendrix and Salehyan (2012) found that violent conflict is more likely to break out in wetter years, suggesting resource wars are more prevalent when there are resources to fight over. In contrast, non-violent conflicts (protests and strikes) are influenced by negative deviations from normal rainfall. The results of Raleigh and Kniveton (2012) are also linked to the type of conflict in question. They find small-scale conflict and communal violence are more likely with higher than average rainfall while rebel conflict is more likely in drier conditions.

3. Study area

We focus on Sub-Saharan Africa because the effects of climate change on the African continent are expected to be severe (Witmer et al., 2017; IPCC, 2018; Ahmadalipour et al., 2019). Temperatures on the continent are projected to rise faster than the global average during the 21st century as are changes in rainfall patterns (IPCC, 2018). Several demand-side pressures are also anticipated as the population grows and level of development increases (Böhmelt et al., 2014; Buhaug et al., 2015). Further, many African countries do not have well-developed irrigation systems and are dependent upon rain-fed agriculture, making changes in rainfall potentially problematic to the food supply. In addition, many households lack access to running water (Wutich et al., 2017; Dos Santos et al., 2017; Nhamo et al., 2019), which makes individuals susceptible to changing rainfall patterns. These changes in precipitation could be exacerbated by the poor institutional quality of many countries on the continent (Michalopoulos and Papaioannou, 2016) and limited adaptive capacity (Sarkodie and Strezov, 2019).

4. Data

4.1. Armed Conflict Location and Event Dataset (ACLED)

We use the Armed Conflict Location and Event Dataset (ACLED) to measure conflict in Africa (Raleigh et al., 2010). ACLED contains geocoded, point-level data with the date for all reported conflict events in 55 countries[1] in Africa. Each country in the dataset is classified into one of five regions – North, East, West, Central, or Southern (Raleigh et al., 2010). Table 1 includes a list of all countries in ACLED as well as which countries are included in each region.

Table 1
ACLED Delineation of African Regions.

Central Africa	Angola, Cameroon, Chad, Central African Republic, Democratic Republic of Congo, Equatorial Guinea, Gabon, Republic of Congo/Congo Brazzaville
East Africa	Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Rwanda, Somalia, Tanzania, Uganda
North Africa	Algeria, Egypt, Libya, Morocco, Sudan, Tunisia, Western Sahara
Southern Africa	Botswana, Swatini/Swaziland, Lesotho, Namibia, South Africa, Zambia, Zimbabwe
West Africa	Benin, Burkina Faso, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast/ Cote d'Ivoire, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo

Note 1: This paper treats South Sudan as part of Sudan and Somaliland as part of Somalia.
Note 2: ACLED recorded no events for the islands of Cape Verde, Comoros, and Sao Tome and Principe.

Table 2
ACLED definition of conflict types.

Battles	a violent interaction between two politically organized armed groups at a particular time and location
Explosions/Remote violence	one-sided violent events in which the tool for engaging in conflict creates asymmetry by taking away the ability of the target to respond
Violence against civilians	violent events where an organized armed group deliberately inflicts violence upon unarmed non-combatants
Riots	violent events where demonstrators or mobs engage in disruptive acts
Protests	a public demonstration in which the participants do not engage in violence, though violence may be used against them
Strategic developments	contextually important information regarding the activities of violent groups that is not itself recorded as political violence, yet may trigger future events or contribute to political dynamics within and across states

Note: In this paper "Violent Events" are battles, explosions/remote violence, violence against civilians and riots. "Nonviolent events" are protests and strategic developments.
Source: https://www.acleddata.com/2019/03/14/acled-introduces-new-event-types-and-sub-event-types/

The ACLED event types include: protests, riots, remote violence/explosions, battles, strategic development, and violence against civilians. In addition, the different types of events are classified as violent and nonviolent events. Protests and strategic developments are considered nonviolent events. The other four event types are categorized as violent events. Table 2 provides the ACLED definitions for each type of conflict.

In early work on climate change and conflict, many researchers used countries as the unit of analysis (Gleick and Heberger, 2014; Grey et al., 2009; Homer-Dixon, 1994; Siddiqi and Anadon, 2011). There is likely an endogeneity problem with this unit of analysis in Africa because Europeans imposed random borders when creating country boundaries on the continent (Salehyan, 2008). Evidence in favor of this line of reasoning was provided by Michalopoulos and Papaioannou (2016) who showed that the former homelands for split groups tended to experience more violence. To solve this problem, Salehyan (2008) suggests the use of smaller, exogenous units of observation, arguing that these small areas cannot drive national level policy changes.

Therefore, we use 0.5° by 0.5° resolution grid cell data as our unit of analysis. To create our dataset, we created an empty grid at a 0.5° by 0.5° resolution. Then, we assigned every ACLED event between 1997 and 2018 to the appropriate grid cell. The assignment of points to grid cells was stratified in multiple fashions: (1) all conflict, (2) violent and

[1] There are two states whose independence is disputed in Africa – Western Sahara and Somaliland. In our analysis, Western Sahara is classified as Morocco and Somaliland is classified as Somalia.

nonviolent conflict events, and (3) event type. As mentioned previously, we focus on the Central, East, West, and Southern regions within Sub-Saharan Africa. We exclude North Africa, as the sociocultural contexts there are distinct from those in Sub-Saharan Africa, reducing the interpretability of estimates and reliable comparisons with the other regions.

For each cell and conflict type, we calculated the average number of events across the 22 year sample period. The long-term average number of conflict events was then subtracted from the annual number of conflict events in that grid cell. This de-meaning indicates whether a grid cell is above or below its long-term average. In other words, negative numbers indicate a year when events in a given cell were below its long-term mean and positive numbers indicate a year that events were above the long-term mean. We refer to the former as periods of peace and the latter as periods of conflict. This serves as a means of normalizing conflict levels so that one region which experiences a significant amount of conflict in general does not bias the results based on a global mean. For example, cells straddling the border between the Democratic Republic of Congo and Uganda tend to have higher levels of conflict.

Fig. 1 shows the distribution of all conflict events as well as violent and non-violent conflicts across the four study regions.

In terms of all conflict, East Africa has the highest number of events compared to the rest of Sub-Saharan Africa. Southern Africa had the lowest incidence of conflict. East Africa also had the highest incidence of violent conflict followed by Central Africa. It is not surprising that these two regions have the highest incidence of conflict given several notable events between 1997 and 2018. In 1998, Ugandan troops became involved in rebel uprisings in the Democratic Republic of Congo (formerly Zaire) (U.N., 1999). In 2010, twin bombings in Kampala, Uganda occurred; a member of the Islamist group al-Shabaab was found guilty of organizing these attacks (Aglionby, 2016). In 2013, a five-year civil war broke out in the South Sudan in East Africa, which resulted in the deaths of 400,000 people (Council on Foreign Relations, 2018). To this day, the South Sudan is considered one of the most dangerous countries in Africa (The Telegraph, 2020). The Democratic Republic of Congo is located in Central Africa and is a site of ongoing conflict. For example, the Second Congo war involving troops from several neighboring countries occurred between 1998 and 2003 (Council on Foreign Relations, 2020). In 2012, deserters from the Congolese army rebelled against the government in what is referred to as the M23 Movement in response to what they perceived to be a violation of a peace deal signed in 2009 between the DRC and Rwanda (BBC News, 2013; Council on Foreign Relations, 2020).

Fig. 2 depicts the number of conflicts by event type for each region. This figure highlights that within each region, there are differences in the frequency of conflict types. For example, in Central and East Africa, the majority of conflicts are battles and violence against civilians. In West Africa, violence against civilians and protests comprise the largest number of events. In Southern Africa, protests, riots, and violence against civilians are the more common types of conflict.

4.2. Rainfall data

We use the Climate Hazards Group Infrared Precipitation with Station data v2.0 (Climate Hazards Center, 2020; Funk et al., 2015) for our precipitation measures. The CHIRPS data are reported monthly from 1981 to the present at the 0.05 degree (~5 km) resolution. The rainfall data come from satellite data and observational data from rain gauges which are then interpolated to produce precipitation raster (gridded) data (Funk et al., 2015). This combination of remotely sensed data from satellites and weather station data is important because it mitigates several of the issues of using rainfall data. For example, Schultz and Mankin (2019) suggest that conflict affects the measurement of weather because stations may be lost during periods of conflict which affects the ability to accurately measure climatic conditions. Such a situation would bias estimates obtained from stations downwards. Therefore, a combination of satellite data, which is not likely to be interrupted by conflict, and rain gauge data mitigates this issue.

To match the data availability from the ACLED database, we use the CHIRPS data from 1997 to 2018. We compute both the monthly and

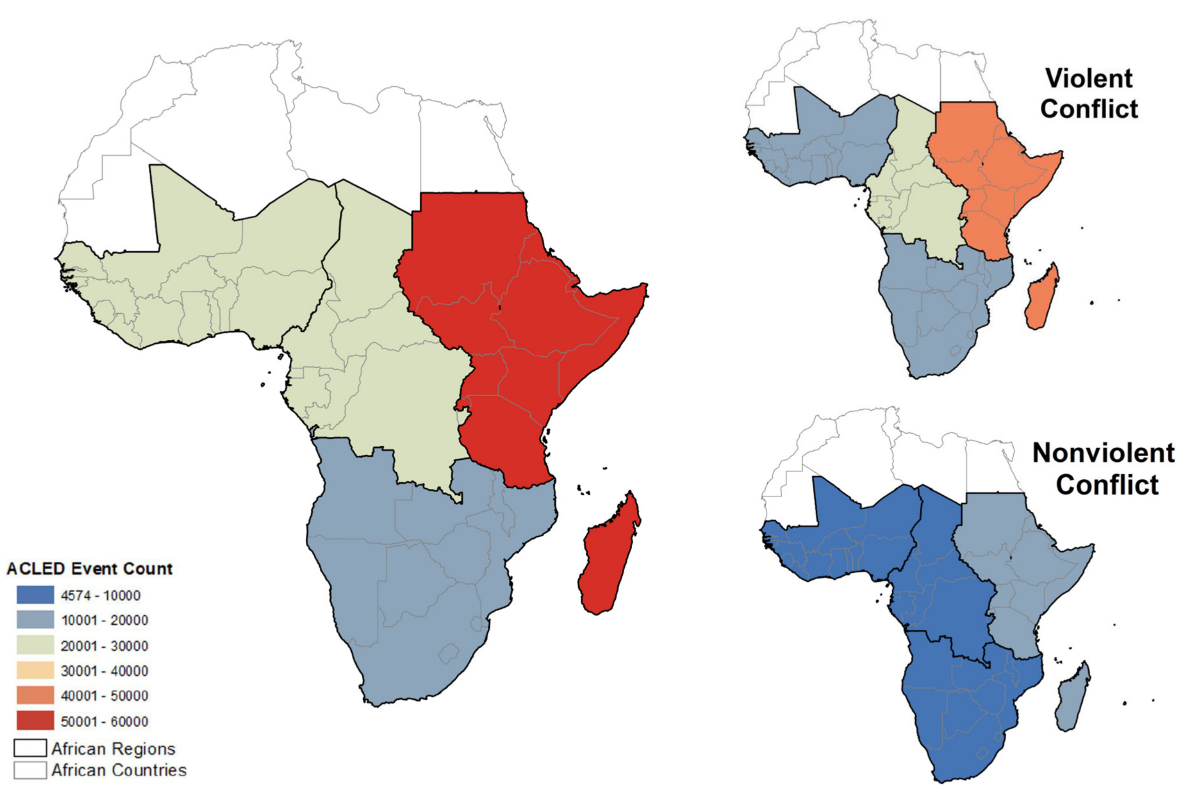

Fig. 1. Distribution of conflict events by Sub-Saharan African Region (1997–2018).

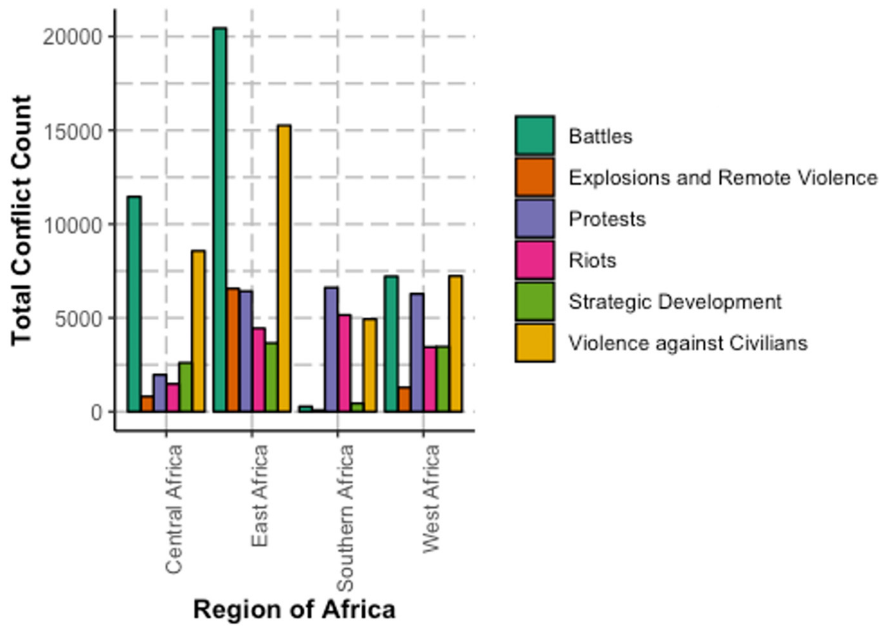

Fig. 2. Count of Conflict Event Types by Sub-Saharan African Region (1997–2018).

annual deviations of rainfall from its 22-year mean. To align these datasets, we first calculated the monthly and annual level of precipitation for each cell. Then, we calculated the long-term average (22-years) monthly and annual precipitation for each grid cell. Next, we differenced the monthly precipitation from the long-term monthly average and followed a similar procedure for the annual data. In our estimation, we include two sets of variables for rainfall: (1) the annual standard deviation of a grid cell; and (2) twelve monthly variables that receive a value of 1 if precipitation in that grid cell in a given month is above the long-term mean and a 0 if it is at or below its long-term mean.

We focus on monthly deviations from the long-term average instead of annual or seasonal measures of rainfall for two reasons. First, monthly deviations from the long-term average prevent persistently drier or wetter grid cells from driving our results. Second, monthly data allows us to see how the subtleties of climate change, such as a change in the length of the seasons, affects the likelihood of conflict. For example, if climate change causes the dry season to last longer, that disruption in the transitional month may be especially impactful on conflict in the region.

Seasonal differences in rainfall are particularly important in Africa, as there are stark differences in seasonality because the continent straddles the equator. This means each of the four regions of Sub-Saharan Africa have specific wet and dry seasons. In East Africa the wet season is from February to May and then again from October to December. In West Africa, the wet season is from April to October, while in Southern Africa the wet season is from October to April. Central Africa does not have seasons. That said, July, August and September are comparatively wetter than the other nine months of the year. These variations in seasons are important to note because much of the economy on the African continent is agriculturally oriented. For field/row crops, the planting season is the beginning of the rainy season and the harvest is at the end of the rainy season/start of the dry season.[2] Deviations in rainfall can change the planting season and destroy crops during the harvest season.

Summary statistics in Table 3 indicate significant variation across regions with regards to rainfall each month. This reinforces the importance of looking at both monthly and regional rainfall measures in our analysis. Given the variation in the rainy season across the continent and its impact on the harvest, we hypothesize that the effects of monthly changes in rainfall on conflict will vary regionally.

4.3. Other controls

We include controls for the annual mean and variance of temperature to allow for the possibility that changes in temperature are driving results. These data were extracted from the Matsuura and Wilmott (2001) temperature database at the monthly level and aggregated to the annual level. In addition, we include controls for gross domestic product (GDP) and the percentage of the population that is urban at the country level, both obtained from the World Bank. GDP is deflated using the consumer price index (CPI) for all urban consumers (Federal Reserve Bank of St. Louis, n.d).

5. Methodology

5.1. Markov transition matrices

We create our dependent variable for the logit models discussed later in Section 5.2 by designating years of below average conflict as 0 and years of above average conflict as 1 for each grid cell. The logit regression will allow us to quantify how rainfall contributed to the observed transition from below average conflict to above average conflict in particular cells. In order to provide context for those results, we first summarize the transitions at the cell level using Markov transition matrices. To do this, we compute the total number of cells in a state of peace or in a state of conflict in a given year. The resulting Markov matrix conveys the probability that a random grid cell currently in one state either transitions to the other state or remains in the same state the following year. While this does not tell us why any particular cell changed, it provides a useful point of reference for understanding the duration of conflict.

By construction, Markov transition matrices are “memoryless” in that they only use information from the previous period. While this assumption may be problematic when studying conflict, we address this concern by considering the deviation from the long-term average for a given cell. For example, a “peaceful” cell below its long-term average may have a 95% chance of remaining below the cell's long-term average

[2] For more information on the crop calendars, see: http://www.fao.org/agriculture/seed/cropcalendar/searchbycountry.do

Table 3
Summary statistics.

	Sub-Saharan Africa	East Africa	Central Africa	West Africa	Southern Africa
Countries	42	12	8	15	7
Total conflict events	130,120	56,790	26,887	28,929	17,514
Violent conflict	98,655	46,706	22,313	19,183	10,453
Non-violent conflict	31,465	10,084	4574	9746	7061
Battles	39,398	20,443	11,459	7216	280
Explosions & remote violence	8737	6560	807	1287	83
Violence against civilians	35,991	15,259	8567	7231	4934
Riots	14,529	4444	1480	3449	5156
Protests	21,288	6424	1967	6279	6618
Strategic developments	10,177	3660	2607	3467	443
Annual std dev of precipitation	58.90	77.17	75.30	60.48	46.79
Mean annual temperature	526.58	445.05	529.07	859.00	125.38
Variability in annual temp	546.92	611.08	400.19	644.43	563.52
Jan average rainfall	70.37	124.74	87.95	3.07	103.87
Jan standard deviation of rainfall	95.00	139.32	81.25	6.79	76.19
Feb average rainfall	62.72	98.73	88.16	7.44	89.40
Feb standard deviation of rainfall	76.98	107.28	70.89	16.55	61.30
Mar average rainfall	74.58	109.22	123.09	17.87	74.67
Mar standard deviation of rainfall	78.67	91.80	82.82	36.85	50.06
Apr average rainfall	63.69	96.44	109.68	30.98	29.76
Apr standard deviation of rainfall	67.10	69.01	74.79	49.42	15.79
May average rainfall	50.12	60.44	85.58	54.74	9.02
May standard deviation of rainfall	65.95	59.49	77.35	73.44	9.34
Jun average rainfall	44.68	33.97	65.82	87.55	6.75
Jun standard deviation of rainfall	75.31	54.21	77.57	105.45	10.74
Jul average rainfall	57.11	43.71	77.50	121.67	5.52
Jul standard deviation of rainfall	94.56	75.55	96.01	124.97	10.83
Aug average rainfall	69.14	45.50	97.32	149.67	6.56
Aug standard deviation of rainfall	108.07	77.26	105.69	143.46	11.44
Sep average rainfall	62.79	35.38	106.76	118.03	9.02
Sep standard deviation of rainfall	91.16	52.21	94.52	119.02	12.04
Oct average rainfall	66.44	51.78	141.01	61.07	24.73
Oct standard deviation of rainfall	84.98	43.85	104.65	87.87	20.58
Nov average rainfall	60.47	66.44	118.74	15.74	54.72
Nov standard deviation of rainfall	69.72	46.65	93.20	38.28	38.52
Dec average rainfall	68.68	101.06	107.05	5.10	89.70
Dec standard deviation of rainfall	82.91	88.71	96.34	13.11	73.97
National GDP	253,647,140.42	85,488,801.43	111,834,125.99	19,0708,173.60	464,862,727.74
Percent urban of country	43.01	36.66	43.23	35.15	49.76

Note: Summary statistics are for the country a cell was assigned to and the regions are based on ACLED definitions.

conflict level the next year and a 5% chance of transitioning above its long-term conflict average the next period.

We calculate these transition matrices for total conflict across Sub-Saharan Africa, as well as for each type of conflict. This is important because the persistence of conflict likely varies by conflict type. For example, we expect explosions & remote violence to be more random than protests. In addition, we break up our analysis by the different regions in Sub-Saharan Africa – East, Central, West, and Southern. This allows us to capture differences in culture, seasons, and other regional trends that may be present. In our logit model, we focus on the probability that a cell transitions from a state of peace into a state of conflict.

5.2. Logit panel model

To test our hypothesis that positive deviations from the long-term average amount of rainfall (i.e. more rain than normal) affect conflict persistence, we incorporate information from the Markov analysis into a panel logit model with the following specification:

$$Y_{it} = \rho ANNDEV_{it} + \Upsilon \mathbf{MONDEV}_{it} + X_{it} + \alpha_i + e_{it} \quad (1)$$

In this model, the dependent variable takes on a value of 1 if grid cell *i* transitioned from peace to conflict in year *t* and a 0 if it remained at peace. $ANNDEV_{it}$ is the annual standard deviation in rainfall for the grid cell. $\mathbf{MONDEV}_{it}$ represents monthly indicator variables for whether rainfall was above the long-term average for that particular month. In other words, a grid cell receives a value of 1 if precipitation in that grid cell in a given month was above the long-term monthly mean and a 0 if precipitation was equal to or below the long-term mean. In the interest of space, we focus on the above average rainfall results. The results are consistent with examining below average rainfall, meaning the results are similar in magnitude but in the opposite direction. X_{it} are the control variables, specifically, GDP, urban concentration, and the temperature variables. a_i are grid-cell fixed effects and e_{it} is a stochastic error term. Models are estimated with bootstrapped standard errors which do not assume a particular distribution to the error term.

The model is run for all conflict events, only non-violent conflict events, only violent conflict events, and each of the individual conflict events listed in Table 2. In addition, we stratified our results across regions of Sub-Saharan Africa – East, Central, West, and Southern. We do this because, given the size of the continent and the fact that it straddles the equator, there are distinctly different wet and dry seasons across the regions. Failure to account for these seasonal variations will bias our estimates towards zero.

6. Results

6.1. Markov transitional probability results

Table 4 presents the Markov transitional probabilities for all conflict, all violent conflict, and all nonviolent conflict for each region in Sub-Saharan Africa. Column 1 reports the likelihood that a cell at peace remains in peace in the next year and column 2 reports the probability a cell transitions to a state of conflict. Column 3 reports the probability a cell in conflict transitions to peace in the next period and column 4 the probability that a cell in conflict remains in conflict. Columns 5–8

Table 4
Markov transitional probabilities by region: violent and non-violent events.

	All				Violent				Non-Violent			
	1	2	3	4	5	6	7	8	9	10	11	12
Region	Peace, Peace	Peace, Conflict	Conflict, Peace	Conflict, Conflict	Peace, Peace	Peace, Conflict	Conflict, Peace	Conflict, Conflict	Peace, Peace	Peace, Conflict	Conflict, Peace	Conflict, Conflict
East Africa	0.924	0.076	0.616	0.384	0.927	0.073	0.621	0.379	0.964	0.036	0.691	0.309
Central Africa	0.956	0.044	0.642	0.358	0.959	0.041	0.641	0.359	0.982	0.018	0.702	0.298
West Africa	0.95	0.05	0.630	0.370	0.953	0.047	0.646	0.354	0.976	0.024	0.633	0.367
Southern Africa	0.957	0.043	0.673	0.327	0.964	0.036	0.668	0.332	0.973	0.027	0.733	0.267

follow the same structure for violent conflict and columns 9–12 for non-violent conflict.

Looking at Table 4, the likelihood that a grid cell at peace remains at peace in the next period is roughly 95% across all regions, indicating that the transition from peace to conflict is rare. However, Table 4 highlights that this transition probability varies regionally. For instance, the probability of transitioning from peace to conflict is 7.6% in East Africa. This probability, while low, is still notably higher than West (5.0%), Central (4.4%), and Southern Africa (4.3%). The transition from conflict to peace is more likely than remaining in conflict across all regions, but is highest in Southern Africa (67.3%) and lowest in East Africa (61.6%). These transition probabilities reflect the relative levels of conflict in each of these regions. As mentioned previously, East Africa has higher levels of conflict than the rest of the study regions and the computed transition probabilities are reflective of this spatial trend.

When we divide conflict into violent and nonviolent events, the Markov results reveal subtle differences. If we focus on the transition from peace to violent conflict, East Africa is the most likely (7.3%) to transition and Southern Africa is the least likely to transition to violent conflict. These probabilities are consistent with the incidence of violent conflict in these regions as presented in Fig. 1. East Africa is also the most likely to experience conflict persistence (37.9%); in other words, once a grid cell transitions into a state of conflict it is more likely to remain in conflict.

If we examine the transition from peace to nonviolent conflict, a somewhat different pattern emerges. East Africa is the most likely to transition from a state of peace to a state of nonviolent conflict (3.6%). The next most likely region to transition from peace to nonviolent conflict is Southern Africa (2.7%) followed by West Africa (2.4%) and then Central Africa (1.8%). This reflects the types of conflict taking place in each region (Fig. 2). Southern Africa has a higher incidence of protests. West Africa also has a high incidence of protests and the highest incidence of nonviolent conflict persistence (36.7%).

Table 5 reports Markov transitional matrices by conflict event type. We focus on the transition from a state of peace to conflict because this will be the focus of the panel logit models.

The table shows that the probability of transitioning into conflict varies by region and by conflict type. This is important because it suggests that the type of conflict and the geography in question matter. For example, East Africa has the highest likelihood of transitioning from peace to conflict for battles (4.7%) and also for violence against civilians (4.7%). This is not surprising given the five year civil war in the South Sudan from 2013 to 2018 (Council on Foreign Relations, 2018). Southern Africa has a relatively high likelihood of transitioning from a state of peace to conflict for protests, riots, and violence against civilians. These results for Southern Africa could be driven by the political experiences during apartheid, where protests became common and several protests turned into riots. In Central and West Africa, if grid cells transition to a state of conflict, it is likely to be one of three types of conflict: battles, violence against civilians, or riots.

6.2. Logit panel model

We argue that monthly precipitation levels are the appropriate measure when considering the impact of rainfall because of seasonal effects that are lost when using annual measures. For example, the impact of too much rain in one month but too little in another may offset one another with annual measures, causing the true effect to be masked. By disaggregating our analysis to the monthly level, we are better able to determine if these seasonal effects exist.

6.2.1. Seasonal analysis for all conflicts

Table 6 presents our results for the impact of experiencing above average rainfall on all types of conflict. This table highlights two key results.

First, seasonality plays a distinct role in the relationship between rainfall and conflict. As previously mentioned, there are distinct and differing seasons across the African continent resulting in the differing patterns seen in fig. 6. The onset, duration, and end of the wet and or dry season varies across the continent impacting conflict regimes at a monthly scale, hence the monthly scale of analysis. Second, rainfall above the monthly mean increases the incidence of conflict during the dry season. This link is particularly noticeable for West and Southern Africa. In West Africa, the dry season is when households migrate to cities to look for non-farming employment opportunities. Therefore, if there is too much rain, there is a potential mobility impact as flooding may restrict movement. Another explanation is that the majority of mining activity occurs during the dry season and above average rainfall may disrupt this type of work. Such a reduction in work opportunities could reduce household income, leading to increased conflict. In Southern Africa, above average rainfall during the dry season is linked to a transition to conflict. In Central Africa, the general trend is that above average rainfall is more likely to lead to conflict. This could be because too much rain can lead to rotting food stores, saturated garden and field crops, decreased mobility from flooding, and increased rates of communicable and non-communicable disease prevalence. All of these situations may have connections with

Table 5
Markov transitional probabilities from peace to violence by region and conflict type.

Region	Protests	Battles	Explosions & remote violence	Violence against civilians	Riots	Strategic development
Sub-Saharan Africa	0.016	0.027	0.008	0.027	0.016	0.013
East Africa	0.025	0.047	0.013	0.047	0.025	0.021
Central Africa	0.007	0.029	0.005	0.027	0.009	0.015
West Africa	0.019	0.031	0.007	0.029	0.020	0.011
Southern Africa	0.023	0.005	0.001	0.021	0.025	0.007

Table 6
Panel logit results for all conflict types.

Above Average Precipitation					
Region	Sub-Saharan	East Africa	Central Africa	West Africa	Southern Africa
Annual Std Dev of Precipitation	0.993***	0.993***	0.992***	0.997	1.001
	[0.000990]	[0.00132]	[0.00248]	[0.00221]	[0.00256]
Mean Annual Temperature	0.999***	1.001***	0.999***	0.999***	0.999
	[8.76e-05]	[0.000228]	[0.000175]	[0.000256]	[0.000771]
Variability in Annual Temp	1.000***	1.000	1.001***	1.001***	1.000**
	[7.16e-05]	[0.000180]	[0.000129]	[0.000277]	[0.000154]
National GDP	1.000***	1.000	1.000***	1.000*	1.000***
	[5.63e-11]	[3.81e-10]	[7.88e-10]	[1.02e-10]	[1.99e-10]
Percent Urban of Country	1.139***	1.193***	1.211***	1.173***	1.137***
	[0.00627]	[0.0117]	[0.0177]	[0.00952]	[0.0163]
January	1.110***	1.036	1.100	1.296***	0.845**
	[0.0286]	[0.0519]	[0.0660]	[0.0596]	[0.0635]
February	1.019	0.866***	0.998	1.156**	0.995
	[0.0242]	[0.0410]	[0.0446]	[0.0656]	[0.0663]
March	1.101***	1.051	1.285***	0.992	0.992
	[0.0281]	[0.0485]	[0.0695]	[0.0448]	[0.0643]
April	0.935***	1.005	0.916*	0.974	0.861**
	[0.0239]	[0.0420]	[0.0456]	[0.0531]	[0.0643]
May	0.981	1.027	1.062	0.975	0.741***
	[0.0252]	[0.0455]	[0.0555]	[0.0494]	[0.0652]
June	1.02	0.984	0.982	1.042	1.389***
	[0.0250]	[0.0400]	[0.0494]	[0.0566]	[0.0902]
July	1.031	0.993	1.077	1.097	0.964
	[0.0276]	[0.0492]	[0.0503]	[0.0673]	[0.0795]
August	1.050**	0.993	1.131**	0.894	1.172**
	[0.0234]	[0.0425]	[0.0576]	[0.0639]	[0.0855]
September	1.029	0.943	1.087*	0.915	1.190**
	[0.0247]	[0.0378]	[0.0527]	[0.0573]	[0.0901]
October	0.938**	0.952	0.885**	0.978	0.914
	[0.0238]	[0.0413]	[0.0461]	[0.0532]	[0.0662]
November	0.971	0.959	1.051	1.059	0.791***
	[0.0223]	[0.0391]	[0.0547]	[0.0567]	[0.0494]
December	1.153***	1.014	1.193***	1.227***	1.105
	[0.0267]	[0.0503]	[0.0620]	[0.0725]	[0.0766]
Observations	79,024	25,520	22,616	20,592	10,296

Note: * indicates significant at the 10% level, ** indicates significance at the 5% level, *** indicates significance at the 1% level. Standard errors are reported in brackets below each coefficient.

Table 7
Panel logit for all violent conflict.

Above average precipitation					
Region	Sub-Saharan	East Africa	Central Africa	West Africa	Southern Africa
Annual Std Dev of Precipitation	0.993***	0.993***	0.993***	0.997	1.006**
	[0.000765]	[0.00107]	[0.00208]	[0.00259]	[0.00272]
Mean Annual Temperature	0.999***	1.001***	0.999***	0.999***	1.000
	[0.000108]	[0.000273]	[0.000163]	[0.000273]	[0.000759]
Variability in Annual Temp	1.000***	1.000	1.001***	1.001***	1.000**
	[7.31e-05]	[0.000171]	[0.000114]	[0.000258]	[0.000186]
National GDP	1.000**	1.000	1.000***	1.000	1.000***
	[7.50e-11]	[4.22e-10]	[7.64e-10]	[9.95e-11]	[2.12e-10]
Percent Urban of Country	1.131***	1.191***	1.215***	1.164***	1.156***
	[0.00496]	[0.0145]	[0.0187]	[0.00921]	[0.0257]
January	1.122***	1.049	1.095*	1.302***	0.868**
	[0.0243]	[0.0480]	[0.0536]	[0.0696]	[0.0533]
February	0.987	0.836***	1.024	1.08	0.886*
	[0.0277]	[0.0375]	[0.0542]	[0.0580]	[0.0592]
March	1.093***	1.044	1.287***	0.972	1.003
	[0.0268]	[0.0411]	[0.0524]	[0.0451]	[0.0666]
April	0.939**	1.021	0.915*	0.973	0.869*
	[0.0228]	[0.0436]	[0.0447]	[0.0443]	[0.0635]
May	0.990	1.026	1.095	0.951	0.770***
	[0.0259]	[0.0419]	[0.0624]	[0.0476]	[0.0651]
June	1.003	0.935*	0.992	1.063	1.332***
	[0.0265]	[0.0342]	[0.0511]	[0.0551]	[0.0919]
July	1.027	1.022	1.057	1.104	0.894
	[0.0266]	[0.0493]	[0.0488]	[0.0754]	[0.0722]
August	1.04	1.011	1.122**	0.854***	1.182**
	[0.0257]	[0.0476]	[0.0527]	[0.0510]	[0.0792]
September	1.066**	0.981	1.098*	0.984	1.286***
	[0.0300]	[0.0450]	[0.0578]	[0.0626]	[0.0889]
October	0.914***	0.926	0.887**	0.938	0.889
	[0.0270]	[0.0463]	[0.0472]	[0.0494]	[0.0725]
November	0.996	0.996	1.056	1.051	0.843**
	[0.0234]	[0.0417]	[0.0529]	[0.0631]	[0.0664]
December	1.131***	1.011	1.183***	1.157***	1.064
	[0.0270]	[0.0545]	[0.0655]	[0.0565]	[0.0741]
Observations	74,910	24,750	21,824	19,426	8910

Note: * indicates significant at the 10% level, ** indicates significance at the 5% level, *** indicates significance at the 1% level. Standard errors are reported in brackets below each coefficient.

conflict. In East Africa, above average rainfall in February reduces the likelihood of transitioning into conflict, but none of the other months exhibit statistically significant effects.

Tables 7 and 8 present regression results for violent and nonviolent conflict, respectively. As we saw in the Markov results, there are differences across regions in the incidence of violent and nonviolent conflict and these differences persist in our logit analysis. For example, in Southern Africa, above average rainfall during the dry season is related to a higher incidence of violent conflict. In West Africa, above average rainfall in December and January, which is during the dry season, is associated with a high likelihood of transitioning to violent conflict. A similar result holds for nonviolent conflict. In East Africa, there are no clear seasonal patterns between rainfall and conflict. For Central Africa, however, above average rainfall is associated with a higher likelihood of transitioning into both violent and nonviolent conflict, which is consistent with the results for all conflict types and the legacy of conflict in this region.

6.2.2. Seasonal analysis by type of conflict

Tables 9 through 14 present logit model results for each conflict type – battles, explosions and remote violence, violence against civilians, riots, protests, and strategic developments. Table 9 presents the results for battles. Again, seasonality is critical to understanding the relationship between climate and conflict. However, it is not the entirety of the season that plays a critical role but rather the timing of seasonal precipitation and variation from the norm. For instance in East Africa, more rainfall is associated with transitioning from peace to battles during the dry season.

The exceptions to this trend are the months immediately before and after the wet season. This suggests that too much rainfall during planting and harvest seasons increases the likelihood of transitioning to battles. In West Africa, more rainfall in the dry season is associated with a higher likelihood of transitioning from peace to battles. This is consistent with the results for all conflict, where above average rainfall during the dry season led to a higher likelihood of transitioning into conflict. In Southern Africa, more rain at the end of the dry season in September is associated with a higher likelihood of transitioning to battles. In Central Africa the results are mixed; in some months (January, March, May, and December) we find above average rainfall increases the likelihood of transitioning into battles but find the opposite effect in other months (June and October).

The results for explosions and remote violence are reported in Table 10. Explosions and remote violence tend to be random events, as they are a tool for engaging in conflict that creates asymmetry by taking away the ability of a target to respond. Given this randomness, no relationship between rainfall and this type of conflict was

Table 8
Panel logit for all non-violent conflict.

Above average precipitation					
Region	Sub-Saharan	East Africa	Central Africa	West Africa	Southern Africa
Annual Std Dev of Precipitation	0.993***	0.994***	0.995	0.993**	0.996
	[0.00135]	[0.00193]	[0.00367]	[0.00302]	[0.00346]
Mean Annual Temperature	0.999***	1.001***	0.999***	0.998***	1.001
	[0.000117]	[0.000257]	[0.000314]	[0.000319]	[0.00124]
Variability in Annual Temp	1.000	0.999***	1.001***	1.001***	1.000
	[9.57e-05]	[0.000218]	[0.000207]	[0.000351]	[0.000208]
National GDP	1.000***	1.000***	1.000***	1.000	1.000***
	[1.22e-10]	[5.27e-10]	[1.20e-09]	[1.66e-10]	[2.32e-10]
Percent Urban of Country	1.194***	1.196***	1.270***	1.233***	1.155***
	[0.00799]	[0.0161]	[0.0295]	[0.0174]	[0.0195]
January	1.061*	0.956	1.178**	1.340***	0.777***
	[0.0356]	[0.0559]	[0.0940]	[0.111]	[0.0686]
February	1.041	0.959	0.830***	1.240**	1.01
	[0.0449]	[0.0660]	[0.0528]	[0.119]	[0.104]
March	1.083***	0.991	1.379***	1.029	0.983
	[0.0303]	[0.0669]	[0.0875]	[0.0691]	[0.0882]
April	1.019	1.124*	1.003	1.024	0.944
	[0.0387]	[0.0733]	[0.0687]	[0.0799]	[0.0879]
May	1.022	1.074	1.075	1.106	0.817**
	[0.0380]	[0.0582]	[0.0791]	[0.0755]	[0.0810]
June	1.032	1.149*	0.931	1.052	1.075
	[0.0382]	[0.0830]	[0.0776]	[0.0872]	[0.0914]
July	1.086**	1.041	1.336***	1.087	1.028
	[0.0454]	[0.0694]	[0.111]	[0.0853]	[0.111]
August	1.095**	0.959	1.072	1.174**	1.241**
	[0.0486]	[0.0662]	[0.0865]	[0.0956]	[0.112]
September	0.965	0.912	0.891	0.875	1.136
	[0.0370]	[0.0552]	[0.0704]	[0.0734]	[0.118]
October	1.023	1.117**	0.928	1.045	0.888
	[0.0296]	[0.0585]	[0.0671]	[0.0867]	[0.0744]
November	0.970	0.920	0.990	1.048	0.902
	[0.0330]	[0.0549]	[0.0686]	[0.0833]	[0.0877]
December	1.146***	0.949	1.097	1.491***	1.057
	[0.0407]	[0.0632]	[0.0958]	[0.111]	[0.0979]
Observations	47,146	15,092	11,418	12,870	7766

Note: * indicates significant at the 10% level, ** indicates significance at the 5% level, *** indicates significance at the 1% level. Standard errors are reported in brackets below each coefficient.

Table 9
Panel logit for all battles.

Above average precipitation					
Region	Sub-Saharan	East Africa	Central Africa	West Africa	Southern Africa
Annual Std Dev of Precipitation	0.994***	0.993***	0.996	1.000	1.01
	[0.00122]	[0.00143]	[0.00283]	[0.00263]	[0.00770]
Mean Annual Temperature	0.999***	1.001***	0.999***	0.999***	1.001
	[0.000131]	[0.000261]	[0.000182]	[0.000315]	[0.00264]
Variability in Annual Temp	1.000	1.000	1.000*	1.001	1.000
	[0.000109]	[0.000196]	[0.000200]	[0.000357]	[0.000421]
National GDP	1.000*	1.000*	1.000***	1.000	1.000**
	[8.47e-11]	[4.11e-10]	[1.11e-09]	[1.20e-10]	[3.87e-10]
Percent Urban of Country	1.088***	1.163***	1.215***	1.126***	0.986
	[0.00632]	[0.0130]	[0.0252]	[0.0120]	[0.0296]
January	1.240***	1.108**	1.149*	1.540***	0.710**
	[0.0444]	[0.0533]	[0.0958]	[0.112]	[0.124]
February	1.028	0.851***	1.105*	0.976	1.192
	[0.0330]	[0.0520]	[0.0657]	[0.0632]	[0.226]
March	1.127***	1.067	1.270***	0.999	1.164
	[0.0448]	[0.0562]	[0.0630]	[0.0699]	[0.175]
April	0.933**	0.966	0.961	1.020	0.913
	[0.0268]	[0.0577]	[0.0648]	[0.0805]	[0.177]
May	1.028	0.99	1.151**	0.946	0.809
	[0.0342]	[0.0517]	[0.0654]	[0.0643]	[0.190]
June	0.936*	0.882**	0.899**	1.136**	0.827
	[0.0322]	[0.0494]	[0.0482]	[0.0726]	[0.136]
July	1.088***	1.018	1.138**	1.158**	1.273
	[0.0303]	[0.0537]	[0.0609]	[0.0688]	[0.239]
August	1.056*	1.112**	1.069	0.851**	0.786
	[0.0339]	[0.0563]	[0.0651]	[0.0583]	[0.130]
September	1.038	0.95	1.047	0.986	1.488**
	[0.0294]	[0.0524]	[0.0670]	[0.0746]	[0.298]
October	0.919***	0.889*	0.870**	1.012	1.131
	[0.0231]	[0.0557]	[0.0500]	[0.0706]	[0.196]
November	1.001	0.948	1.054	0.995	0.733
	[0.0323]	[0.0493]	[0.0459]	[0.0581]	[0.172]
December	1.159***	1.045	1.167***	1.226***	1.184
	[0.0392]	[0.0552]	[0.0692]	[0.0722]	[0.243]
Observations	52,008	18,062	17,050	14,894	2002

Note: * indicates significant at the 10% level, ** indicates significance at the 5% level, *** indicates significance at the 1% level. Standard errors are reported in brackets below each coefficient.

anticipated. Table 10 does not display many statistically significant results, indicating no clear relationship between rainfall and this conflict type.

Table 11 contains the results for violence against civilians. Here, the seasonal effects by region are mixed. In East Africa, above average rainfall during the rainy season is associated with an increased likelihood of transitioning into violence against civilians. However, for West and Southern Africa, above average rainfall during the dry season results in an increased likelihood of transitioning into violence against civilians. In Central Africa, above average rainfall in December and March only are associated with an increased likelihood of transitioning into conflict.

The results for riots in Table 12 are particularly interesting and reiterate the importance of regional level analyses of climate and conflict. Based on the aggregate results for Sub-Saharan Africa in the first column, few linkages except in the month of December appear to exist. However, at the regional level, some clear patterns emerge, particularly in Southern Africa. In this region, an increased likelihood of transitioning into riots is noticeable when above average rainfall occurs in the dry season.

Table 13 presents the results for protests. Above average rainfall is associated with a greater likelihood of transitioning from peace to protests during the dry season in West and Southern Africa – possibly because residents migrate temporarily into cities to find work (Mueller et al., 2020; Todaro, 1976). If protests are more likely in cities, then the influx of individuals during these months may explain the increase in the likelihood of protests during the dry season. In East Africa, more rain towards the end of the rainy season and during the first month of the dry season in June, is associated with an increased likelihood of transitioning into protests.

Finally, Table 14 presents the results for strategic developments. Recall that strategic developments are information about the activities of violent groups that are not themselves recorded as political violence. Important to the classification of these events is that they themselves are not violent, but may trigger future violent events. Therefore, we expect there to be a mixed signal for these types of events, as they are capturing a lot of different factors. Accordingly, our results are mixed. In East Africa, more rain towards the end of the wet season in May leads to an increased likelihood of strategic developments. However, Southern Africa exhibits the reverse pattern – more rain at the end of the dry season in September is associated with a higher likelihood of strategic developments. In Central and West Africa, no clear pattern emerges.

6.2.3. Control variables

Our logit results indicate that for all of Sub-Saharan Africa, a higher *annual* standard deviation in rainfall decreased the probability of transitioning from peace to conflict (Table 6). However, the effect is relatively small in magnitude and only holds in East and Central Africa. In

Table 10
Panel logit for all explosions and remote violence.

Above average precipitation					
Region	Sub-Saharan	East Africa	Central Africa	West Africa	Southern Africa
Annual Std Dev of Precipitation	0.997	0.994	0.997	1.004	0.995
	[0.00255]	[0.00353]	[0.00682]	[0.00509]	[0.0131]
Mean Annual Temperature	0.999**	1.001	0.999**	0.998***	0.987*
	[0.000263]	[0.000369]	[0.000478]	[0.000418]	[0.00757]
Variability in Annual Temp	1.000	0.999	1.000	1.002***	1.001
	[0.000234]	[0.000360]	[0.000495]	[0.000542]	[0.00102]
National GDP	1.000***	1.000	1.000***	1.000***	1.000
	[1.84e-10]	[1.06e-09]	[2.49e-09]	[3.12e-10]	[1.10e-09]
Percent Urban of Country	1.123***	1.162***	1.097**	1.230***	1.065
	[0.0158]	[0.0253]	[0.0485]	[0.0319]	[0.0953]
January	1.443***	1.244**	1.027	1.946***	1.126
	[0.0986]	[0.109]	[0.162]	[0.274]	[0.456]
February	1.149**	0.878	1.327*	1.146	0.939
	[0.0770]	[0.0923]	[0.200]	[0.189]	[0.558]
March	0.937	0.861	1.258**	0.740**	0.713
	[0.0776]	[0.0966]	[0.145]	[0.100]	[0.327]
April	0.894	1.015	0.671***	1.076	1.32
	[0.0613]	[0.113]	[0.0960]	[0.175]	[0.588]
May	1.076	1.032	0.92	1.15	1.024
	[0.0756]	[0.104]	[0.143]	[0.178]	[0.420]
June	1.116	0.982	1.135	1.425**	1.364
	[0.0886]	[0.108]	[0.206]	[0.201]	[0.454]
July	1.109	1.149	0.894	1.344**	1.414
	[0.0758]	[0.0972]	[0.132]	[0.185]	[0.621]
August	1.121	0.964	0.981	1.255	0.935
	[0.0829]	[0.0902]	[0.150]	[0.208]	[0.455]
September	0.946	0.821**	1.22	0.98	0.531
	[0.0599]	[0.0659]	[0.160]	[0.121]	[0.287]
October	1.028	0.967	1.03	1.303*	0.628
	[0.0592]	[0.0947]	[0.183]	[0.199]	[0.283]
November	0.995	0.95	1.126	0.993	0.616
	[0.0707]	[0.106]	[0.144]	[0.144]	[0.311]
December	1.115	0.863	1.551***	1.025	1.899*
	[0.0821]	[0.104]	[0.248]	[0.165]	[0.682]
Observations	16,016	6842	3718	4906	550

Note: * indicates significant at the 10% level, ** indicates significance at the 5% level, *** indicates significance at the 1% level. Standard errors are reported in brackets below each coefficient.

West and Southern Africa, annual-scale variation does not increase the likelihood of transitioning into conflict as previous studies have suggested (Fjelde and von Uexkull, 2012; Hendrix and Glaser, 2007). Instead, monthly variations pertaining to the wet and dry seasons in each region are more important. In addition to rainfall, two temperature controls were included: mean annual temperature and variability in annual temperature. Both variables were significant for Sub-Saharan Africa and several of the regions. However, the odds ratios on both of these variables is one. Therefore, we can say that for this particular study, higher temperatures do not increase the probability of transitioning into conflict.

For the other control variables, GDP is significant but not different from one and therefore does not increase the probability of transitioning into conflict. For all of Sub-Saharan Africa and for all four component regions, we find higher likelihoods of experiencing a transition into conflict in areas with a higher urban population. One explanation for this finding is the dynamics of conflict, especially when specifying a broad spectrum of conflict from protests to armed conflict. Specifically, riots and political demonstrations often take place in urban centers, driven by the mobilization and congregation of people in centralized locations (Abel et al., 2019). With larger urban populations, there exists a larger likelihood of conflict, and an increased likelihood of conflict evolving into physical violence.

6.2.4. Contextualizing model results

To contextualize these results, information about the quality of institutions and agricultural production of each region were collected from the Center for Systemic Peace (CSP, 2020) and the World Bank, respectively (World Bank, 2020). These variables were not incorporated into the econometric models directly because of endogeneity concerns (Acemoglu and Robinson, 2006; Burke et al., 2015b). However, it is important to highlight these characteristics given prior work which notes that the institutional quality of countries (Hartzell and Hoddie, 2003; Denny and Walter, 2014; Wig and Tollefsen, 2016; Jones et al., 2017) and domestic food security contexts (Weinberg and Bakker, 2015; Jones et al., 2017) may modify or mediate the relationship between water and conflict.

Institutional quality is quantified using the State Fragility Index (CSP, 2020) which evaluates information about state effectiveness and legitimacy. Overall, the index is a measure of countries' governance capacity and resilience in the face of challenges and crises. Fig. 3 provides a breakdown by region of this index, which has a maximum value of 25, and its constituent components (effectiveness score and legitimacy score).[3] Of the four regions, Central Africa has the highest index value for the study period, indicating it has the lowest state capacity for governance and the least amount of resilience to challenges and crises. East Africa has the best institutions of the four regions, as indicated by low index values. These numbers are in fact the reverse of what we found in the results discussed above, which indicate that East Africa was more likely to transition from a state of peace to a state of conflict. At first glance, this suggests institutions are not a key contextual factor in explaining transitions from relative peace to conflict. This finding may be due to the fact that local rather than national institutions in Africa are more closely tied to conflict (Wig and Tollefsen, 2016). Thus, national level institutional measures may be insufficient to capture the local nature of this relationship. Our finding of a lack of relationship between conflict and state vulnerability may also be tied to how conflict is defined. In this study, we determine that a grid cell has transitioned from peace to conflict if its conflict level in a particular year is above its 22 year long-term average level of conflict. In addition, we include grid cell fixed effects in our analysis. Given that we are defining conflict based on a grid cell's own conflict levels, as well as the fixed effects included in our model, we are effectively holding institutional quality for that grid-cell constant.

A somewhat similar pattern emerges when analyzing information about annual cereal yields (wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat, and mixed grains) in kilograms per hectare (World Bank, 2020). These data are a good proxy for food availability which is an important element of food security (Napoli, 2010) and we expect lower cereal yields to be related to transitions into conflict. Fig. 4 displays time-series information by region for cereal yields per 100,000 population. The figure indicates that national level cereal yields and food availability may not be an important modifier of conflict across all regions, as defined in this paper.

The econometric models revealed that East Africa followed by West Africa were more likely to transition into conflict. East Africa, however, has relatively higher cereal yields than the other regions save Southern Africa. Thus, cereal yields may not be a modifier of conflict for this region. They may modify conflict in West Africa, however. Our models identified West Africa as one of the regions more likely to transition to violent conflict. This region also has the lowest cereal yields of all the regions analyzed in this paper, suggesting a connection between food availability and conflict. The results for Southern Africa and Central Africa are mixed. Southern Africa was one of the regions that was least likely to transition to violent conflicts but more likely to transition to non-violent conflict. It also has the highest cereal yields of all the

[3] The index inversely measures institutional quality meaning lower index values represent better institutional quality and higher index values represent worse (i.e. lower) institutional quality.

Table 11
Panel logit for all violence against civilians.

Above average precipitation					
Region	Sub-Saharan	East Africa	Central Africa	West Africa	Southern Africa
Annual Std Dev of Precipitation	0.993***	0.992***	0.996	0.995*	1.004
	[0.00116]	[0.00154]	[0.00314]	[0.00277]	[0.00371]
Mean Annual Temperature	0.999***	1.001***	0.999***	0.998***	1.000
	[0.000117]	[0.000225]	[0.000187]	[0.000297]	[0.00127]
Variability in Annual Temp	1.000**	1.000*	1.001***	1.001***	0.999***
	[9.60e-05]	[0.000213]	[0.000165]	[0.000303]	[0.000179]
National GDP	1.000*	1.000**	1.000***	1.000***	1.000
	[8.30e-11]	[4.62e-10]	[1.25e-09]	[1.05e-10]	[2.95e-10]
Percent Urban of Country	1.123***	1.142***	1.297***	1.137***	1.139***
	[0.00856]	[0.0119]	[0.0322]	[0.0116]	[0.0180]
January	1.052	0.994	0.991	1.212***	0.904
	[0.0382]	[0.0410]	[0.0646]	[0.0765]	[0.101]
February	1.062*	0.949	0.979	1.152**	0.945
	[0.0369]	[0.0572]	[0.0448]	[0.0756]	[0.0824]
March	1.166***	1.219***	1.300***	1.013	0.926
	[0.0316]	[0.0562]	[0.0795]	[0.0633]	[0.0815]
April	0.979	1.071*	0.986	1.004	0.888
	[0.0332]	[0.0425]	[0.0565]	[0.0737]	[0.0897]
May	1.035	1.124**	1.003	1.099	0.694***
	[0.0300]	[0.0566]	[0.0596]	[0.0662]	[0.0769]
June	1.023	0.961	1.001	1.119*	1.413***
	[0.0305]	[0.0542]	[0.0578]	[0.0752]	[0.129]
July	1.015	1.001	1.029	1.137	0.904
	[0.0309]	[0.0536]	[0.0634]	[0.102]	[0.0927]
August	1.014	1.007	1.026	0.876**	1.182*
	[0.0320]	[0.0561]	[0.0627]	[0.0562]	[0.116]
September	1.045	1.015	1.002	1.033	1.079
	[0.0317]	[0.0562]	[0.0649]	[0.0751]	[0.101]
October	0.919**	0.902*	0.987	0.879*	0.969
	[0.0349]	[0.0489]	[0.0663]	[0.0597]	[0.111]
November	1.014	0.962	1.02	1.084	0.957
	[0.0369]	[0.0543]	[0.0565]	[0.0730]	[0.104]
December	1.142***	0.98	1.149**	1.246***	1.184
	[0.0398]	[0.0558]	[0.0724]	[0.0723]	[0.137]
Observations	54,076	18,700	16,082	13,640	5654

Note: * indicates significant at the 10% level, ** indicates significance at the 5% level, *** indicates significance at the 1% level. Standard errors are reported in brackets below each coefficient.

Table 12
Panel logit for all riots.

Above average precipitation					
Region	Sub-Saharan	East Africa	Central Africa	West Africa	Southern Africa
Annual Std Dev of Precipitation	0.996***	0.996**	0.991*	0.999	1.003
	[0.00133]	[0.00181]	[0.00548]	[0.00274]	[0.00377]
Mean Annual Temperature	1.000	1.002***	1.000	0.998***	1.000
	[0.000144]	[0.000372]	[0.000352]	[0.000336]	[0.00171]
Variability in Annual Temp	1.000***	1.000	1.001***	1.002***	1.000
	[0.000127]	[0.000298]	[0.000278]	[0.000392]	[0.000245]
National GDP	1.000	1.000***	1.000***	1.000***	1.000***
	[1.56e-10]	[7.92e-10]	[2.07e-09]	[1.37e-10]	[2.29e-10]
Percent Urban of Country	1.298***	1.280***	1.612***	1.257***	1.207***
	[0.0133]	[0.0216]	[0.0648]	[0.0192]	[0.0190]
January	0.950	1.040	0.957	1.275***	0.767***
	[0.0432]	[0.0791]	[0.104]	[0.115]	[0.0779]
February	0.990	0.908	0.937	1.085	0.945
	[0.0334]	[0.0624]	[0.122]	[0.0736]	[0.0841]
March	0.991	0.903	1.234**	0.948	1.156*
	[0.0430]	[0.0638]	[0.119]	[0.0669]	[0.0991]
April	0.947	0.985	0.831	0.903	0.824**
	[0.0447]	[0.0690]	[0.111]	[0.0669]	[0.0808]
May	0.970	1.052	1.118	0.913	0.906
	[0.0450]	[0.0794]	[0.129]	[0.0676]	[0.0903]
June	0.986	1.111	1.053	0.893	0.899
	[0.0457]	[0.0894]	[0.126]	[0.0728]	[0.0663]
July	1.03	1.025	1.192*	0.946	0.967
	[0.0476]	[0.0840]	[0.111]	[0.0695]	[0.104]
August	1.041	1.08	0.969	0.924	1.207**
	[0.0396]	[0.0801]	[0.129]	[0.0788]	[0.114]
September	1.064	1.081	1.123	0.817***	1.440***
	[0.0414]	[0.0717]	[0.153]	[0.0634]	[0.153]
October	0.913**	0.888*	1.041	0.906	0.799**
	[0.0410]	[0.0556]	[0.113]	[0.0799]	[0.0748]
November	0.989	1.208***	0.836*	1.025	0.772**
	[0.0403]	[0.0803]	[0.0785]	[0.0859]	[0.0873]
December	1.091**	1.069	1.217	1.078	1.042
	[0.0451]	[0.0897]	[0.162]	[0.0721]	[0.109]
Observations	34,474	10,934	5830	10,296	7414

Note: * indicates significant at the 10% level, ** indicates significance at the 5% level, *** indicates significance at the 1% level. Standard errors are reported in brackets below each coefficient.

regions. Thus, food availability as proxied by national-level cereal yields, does not appear to be a modifier of conflict in this region. The same is true for Central Africa which was less likely to transition to conflict but also has some of the lower cereal yields of all the regions between 1997 and 2017. That said, this absence of an association could be a function of differences in the temporal granularity of the cereal yield data which are annual instead of monthly, as well as variations in inter-country food production, transportation and availability, and, maybe most importantly, the distribution of food yields across the population (Watts, 1983). The need for higher temporal and spatial resolution data will be discussed below as a need for advancing research in peace studies.

7. Conclusions and policy implications

Our analysis adds four important results to the climate-conflict literature. First, we find that above average rainfall is associated with a higher likelihood of transitioning into conflict, particularly during the dry season. This finding provides evidence in support of the emerging, though not definitive, consensus that increased rainfall, especially flood events, are more likely to initiate conflict than drought events (Mach et al., 2019; Theisen, 2012; von Uexkull et al., 2016). There are several explanations for this result. Drought periods and associated water scarcity have long been part of the human experience across Africa and many social groups and cultural practices have adopted cooperative strategies to combat such strains. As some studies have indicated, cooperation rather than conflict is the more efficient and likely result of water scarcity (Dabelko and Aaron, 2004; Funder et al., 2012; Link et al., 2016; Roth et al., 2019). Based on this context, it makes sense that water abundance rather than scarcity is linked to conflict as more resources breed such tensions. Additionally, often when there is more water, crop yields are more plentiful and there are more resources to fight over (Klomp and Bulte, 2013; Witsenburg and Adano, 2009), though notably flood events often do not result in this same benefit of increased yield. Lastly, larger scale conflicts (e.g. battles) require resources to undertake which may not be possible during dry periods when there are scarce resources (Humphreys, 2005).

Second, we find that the timing and duration of variations in rainfall matters and that monthly variation in precipitation matters more than annual variation. Specifically, our results indicate that each region has specific months—primarily those associated with prime crop harvest periods—where variations in rainfall significantly influence conflict. Additionally, we find that excess rain during the dry season leads to a higher probability of transitioning into conflict. Overall, these results indicate that it is important to think across multiple spatial and temporal scales because the drivers and patterns between conflict and rainfall will vary accordingly. In this study, using a temporally granular measure

Table 13
Panel logit for all protests.

Above average precipitation					
Region	Sub-Saharan	East Africa	Central Africa	West Africa	Southern Africa
Annual Std Dev of Precipitation	0.996***	0.994***	1.000	0.994**	1.003
	[0.00125]	[0.00220]	[0.00539]	[0.00274]	[0.00457]
Mean Annual Temperature	1.000*	1.001***	1.000	0.999**	1.001
	[0.000150]	[0.000379]	[0.000457]	[0.000369]	[0.00160]
Variability in Annual Temp	1.000**	0.999***	1.001***	1.001	1.000
	[0.000120]	[0.000297]	[0.000310]	[0.000388]	[0.000247]
National GDP	1.000***	1.000***	1.000***	1.000*	1.000***
	[1.22e-10]	[6.32e-10]	[1.89e-09]	[1.69e-10]	[2.51e-10]
Percent Urban of Country	1.257***	1.207***	1.391***	1.253***	1.172***
	[0.00989]	[0.0186]	[0.0568]	[0.0151]	[0.0197]
January	0.964	0.944	1.147	1.132	0.803*
	[0.0517]	[0.0694]	[0.121]	[0.111]	[0.0927]
February	1.05	0.984	0.842	1.151	0.953
	[0.0415]	[0.0821]	[0.105]	[0.109]	[0.126]
March	1.066*	1.134*	1.106	1.054	0.98
	[0.0411]	[0.0807]	[0.118]	[0.0917]	[0.0823]
April	1.043	1.264***	0.966	1.012	0.852*
	[0.0468]	[0.102]	[0.111]	[0.0928]	[0.0823]
May	0.926	1.084	1.003	0.903	0.759**
	[0.0439]	[0.0928]	[0.125]	[0.0649]	[0.0814]
June	1.059	1.260***	0.823	1.021	1.022
	[0.0451]	[0.104]	[0.123]	[0.0837]	[0.0887]
July	0.995	0.939	1.096	1.023	1.081
	[0.0444]	[0.0695]	[0.147]	[0.0754]	[0.105]
August	0.999	0.828***	0.898	1.096	1.260***
	[0.0372]	[0.0601]	[0.116]	[0.100]	[0.110]
September	1.021	1.042	0.991	0.908	1.098
	[0.0475]	[0.0901]	[0.107]	[0.0757]	[0.114]
October	1.019	1.07	1.046	1.039	0.885
	[0.0445]	[0.0763]	[0.137]	[0.0974]	[0.0870]
November	1.026	0.944	1.216	1.171**	0.814**
	[0.0437]	[0.0692]	[0.145]	[0.0859]	[0.0825]
December	1.097**	0.808***	1.172	1.401***	1.112
	[0.0414]	[0.0570]	[0.145]	[0.136]	[0.116]
Observations	33,704	11,528	5258	9812	7106

Note: * indicates significant at the 10% level, ** indicates significance at the 5% level, *** indicates significance at the 1% level. Standard errors are reported in brackets below each coefficient.

Table 14
Panel logit for all strategic developments.

Above average precipitation					
Region	Sub-Saharan	East Africa	Central Africa	West Africa	Southern Africa
Annual Std Dev of Precipitation	0.995***	0.998	0.990***	1.000	0.996
	[0.00150]	[0.00226]	[0.00385]	[0.00488]	[0.00474]
Mean Annual Temperature	0.999***	1.001***	0.998***	0.998***	1.002
	[0.000164]	[0.000309]	[0.000294]	[0.000394]	[0.00222]
Variability in Annual Temp	1.000	0.999***	1.001***	1.001***	0.999**
	[0.000136]	[0.000256]	[0.000190]	[0.000415]	[0.000337]
National GDP	1.000	1.000***	1.000***	1.000	1.000
	[1.47e-10]	[7.28e-10]	[1.09e-09]	[2.33e-10]	[4.28e-10]
Percent Urban of Country	1.141***	1.190***	1.274***	1.204***	1.092***
	[0.0137]	[0.0198]	[0.0317]	[0.0228]	[0.0371]
January	1.135**	0.939	1.190**	1.589***	0.774*
	[0.0562]	[0.0766]	[0.0843]	[0.183]	[0.109]
February	1.067	0.938	0.853*	1.418**	1.118
	[0.0469]	[0.0626]	[0.0697]	[0.193]	[0.185]
March	1.127**	0.902	1.609***	0.905	0.861
	[0.0640]	[0.0792]	[0.127]	[0.111]	[0.130]
April	0.99	1.079	1.000	0.913	1.325
	[0.0540]	[0.0939]	[0.0722]	[0.0860]	[0.228]
May	1.251***	1.209**	1.165*	1.613***	1.164
	[0.0484]	[0.0922]	[0.0996]	[0.169]	[0.254]
June	0.933	0.935	0.893	1.038	1.023
	[0.0533]	[0.0730]	[0.0771]	[0.0796]	[0.141]
July	1.116**	1.036	1.414***	1.245**	0.787
	[0.0511]	[0.0854]	[0.110]	[0.133]	[0.141]
August	1.158***	1.136	1.152*	1.052	1.242
	[0.0473]	[0.109]	[0.0885]	[0.147]	[0.220]
September	0.97	0.844**	0.968	0.805**	1.528***
	[0.0561]	[0.0723]	[0.0820]	[0.0848]	[0.241]
October	1.016	1.185*	0.939	1.059	0.665**
	[0.0477]	[0.104]	[0.0799]	[0.129]	[0.123]
November	0.963	0.870*	1.025	0.903	0.933
	[0.0458]	[0.0633]	[0.0772]	[0.105]	[0.151]
December	1.092*	0.984	1.014	1.364**	1.069
	[0.0513]	[0.0979]	[0.0809]	[0.181]	[0.183]
Observations	29,304	9746	9856	7260	2442

Note: * indicates significant at the 10% level, ** indicates significance at the 5% level, *** indicates significance at the 1% level. Standard errors are reported in brackets below each coefficient.

of rainfall is important as we could not highlight the aforementioned trends without such data.

Third, we find important regional variations in the linkage between rainfall and conflict type. These variations are related to the types of conflict that predominate in particular regions of Sub-Saharan Africa as well as variations in the wet and dry season. For example, in Southern Africa, protests and riots are the more common type of conflict occurrence and are more likely to occur when there is above average rainfall at the end of the dry season. These results are important because they flag particular times of year when specific types of conflict are more likely than others.

Finally, the definition of conflict used in this study differs from prior research. We examine the probability that a grid cell within a given region transitions from a state of peace (i.e. below or average levels of conflict) to above average conflict. This approach takes into account the current state of conflict, as defined by ACLED, within a given region and moves beyond prior studies that use binary variables that take on a value of 1 for any incidence of conflict (Harari and Ferrara, 2018). From a policy perspective, this is valuable because it helps us understand whether climatic factors are associated with more conflict than average rather than any conflict at all. In places with a history of violence, such as the Democratic Republic of Congo or the South Sudan, this may be a better modeling strategy than binary or count variables of conflict.

Another important facet of our results is that they can help policy makers prepare for particular types of conflict. For example, for protests and riots, additional police at particular times of year may be helpful in mitigating the incidence and effects of these types of conflict. Another strategy for conflict mitigation may be policies that provide financial support for farmers or other sectors, such as mining, that are impacted by rainfall patterns. For other types of conflict that are more or less random, such as explosions and remote violence, other steps to improve the overall stability of the region may prove useful.

That said, there are some limitations to the present work. First, the results of this paper find statistically significant relationships between rainfall and conflict. This does not mean that rainfall causes conflict. Instead, rainfall should be viewed as facilitating conflict where social, political, economic, and institutional conditions are already conducive to these events. Second, this paper did not investigate specific mechanisms through which changes in rainfall result in conflict, such as commodity prices and water access. Exploring these mechanisms at the same high spatial and temporal resolution that we analyze here is recommended for future research. Third, this paper did not incorporate spatial effects in the estimation of model results—e.g., the effects of neighboring grid cells on each other. Extensions to this paper could examine the impact of spatial effects on transitions to conflict. This would answer a somewhat different research question than the one investigated in the present paper. Specifically, it would answer the question: What is the probability

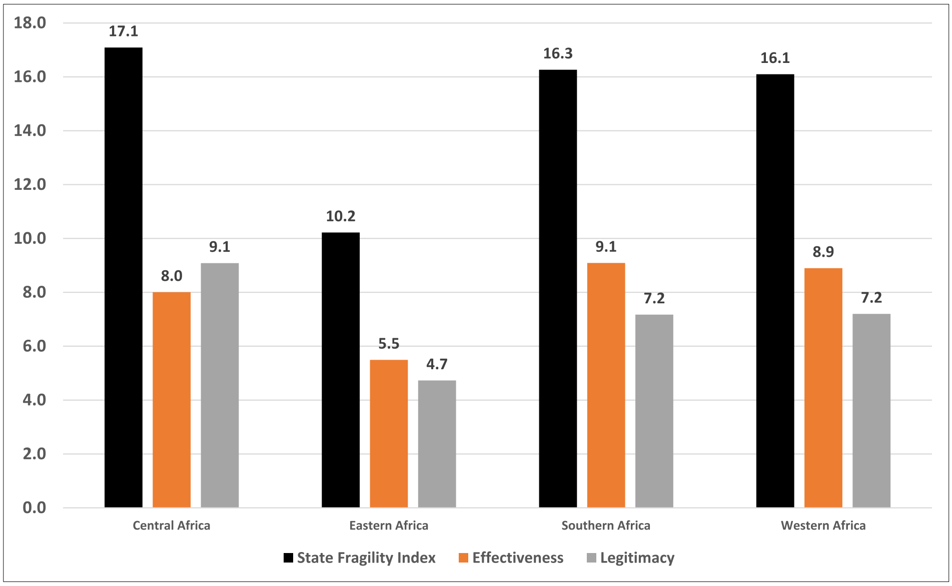

Fig. 3. State Fragility Index and Index Components (1997–2018).

of transitioning into an above average state of conflict given that a neighboring grid cell transitioned into an above average state of conflict? Another extension is to apply the analytical approach used in this paper to other regions of the world, such as Latin America and Southeast Asia.

Lastly, high temporal and high spatial resolution data are needed to analyze associations between conflict and other factors (e.g. governance quality and food security) which may modify the relationship between rainfall and conflict. While studies have been successful in using higher resolution crop (von Uexkull et al., 2016; Crost et al., 2018) and governance data (Wig and Tollefsen, 2016), these studies are exceptional and may even focus on only one country (Crost et al., 2018) to minimize the challenges associated with finding and incorporating sub-national, seasonal data into analyses, particularly at the continental scale. In this respect, the availability of fine grained, longitudinal temporal and spatial data are a noted limitation to peace studies research (Buhaug et al., 2015). The creation of public data repositories that contain longitudinal high resolution information about contextual factors (e.g. food security, institutional quality) that may be linked to conflict would greatly advance peace studies as has the creation of longitudinal high resolution time series data about conflict (Raleigh et al., 2010; UCDP, 2021).

As the world's population continues to grow and global climatic conditions continue to evolve (Henderson and Loreau, 2020), the specter of conflict over scarce resources, including increasingly variable water resources, persists. This paper found positive deviations from local rainfall averages, particularly during the dry season, are linked to the onset of above average conflict. Given variations in culture, climate, and water resources globally, work on climate and conflict that considers these nuances is key to understanding the propensity for conflict in the years to come.

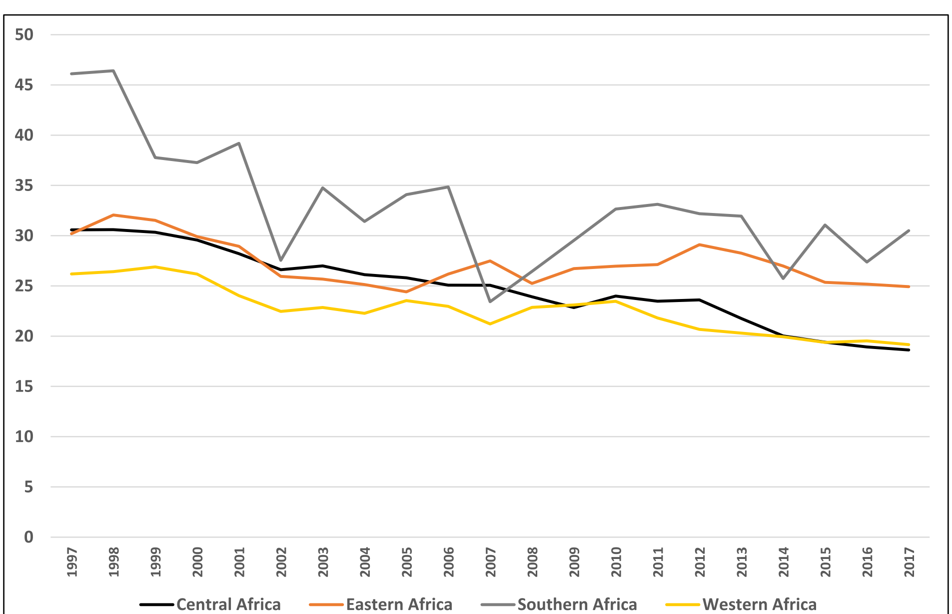

Fig. 4. Cereal Yield (kg per hectare) per 100,000 Population (1997–2017).

CRediT authorship contribution statement

Elizabeth A. Mack: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Visualization, Project administration, Funding acquisition. **Erin Bunting:** Methodology, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration, Funding acquisition. **James Herndon:** Methodology, Conceptualization, Formal analysis, Data curation, Writing – original draft, Writing – review & editing. **Richard A. Marcantonio:** Writing – original draft, Writing – review & editing. **Amanda Ross:** Conceptualization, Methodology, Validation, Formal analysis, Writing – original draft, Writing – review & editing, Project administration. **Andrew Zimmer:** Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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