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Local conflict and climate anomalies in Sudan and South Sudan

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Abstract

This report explores the association between climate anomalies, population dynamics, conflict and organised violence in Sudan and South Sudan, at the sub-national level and for the years 1989-2015. The analyses are conducted using a spatial approach and with geocoded information on organized violence events, climate anomalies and population dynamics. Our results indicate a positive correlation of temperature anomalies with conflict and organised violence at the local level. Precipitation anomalies also positively correlate with organised violence, but to a lesser extent than temperature anomalies. We further explore the climate-security nexus in rural and urban environments in the two countries. Urban areas appear more vulnerable to the risk of organised violence, with the latter positively associated with temperature and precipitation anomalies, as well as with positive net migration. In less densely populated areas, violence is associated with climate anomaly values, though the correlation is lower than in densely populated areas. These results are also confirmed by the analysis based on the number of violent events. Finally, we observe a strong temporal dependence of violent events at the sub-national level.[1]

[1] This technical report is derived from the case study analysis on Sudan and South Sudan contained in McMahon et al. (2021), as part of the Climate Change Induced Migration (CLICIM) project. For more information on the project, follow the link https://knowledge4policy.ec.europa.eu/migration-demography/climate-change-induced-migration-clicim-project_en.

1 Introduction

The climate change-security nexus has gained prominence on the EU political agenda in recent years. As outlined in the EU Global Strategy for Foreign and Security Policy, the European Green Deal and the EU Climate Adaptation Strategy[2], climate change has been recognised as a multiplier of conflict threats and a source of instability. In response to increased political interest, research into the nexus has proliferated rapidly, showing that climate change does not directly cause conflict, but rather increases the probability of conflict or amplifies conditions of underdevelopment, fragility, and internal violence (Mustasilta, 2021) through the interactions with a community's vulnerabilities (Masson-Delmotte et al., 2018; von Uexkull and Buhaug, 2021). Sudan and South Sudan are ranked among the most vulnerable countries in the world to climate change.[3] These two countries are experiencing a steady increase in the frequency and severity of climate-induced floods, droughts and epidemics (UNEP (2018)), with major impacts on livelihoods and the affected population. In addition, these climate emergencies occur within a very fragile security environment, marked by devastating wars, high casualty numbers, widespread violence[4], severe underdevelopment, and low capacity to mitigate and adapt to the changing climate.

The mechanisms linking climate change to conflict mainly concern the deterioration of the living conditions of fragile communities dependent on agriculture and natural resources, as well as changes in pastoral mobility and migration which potentially increase the economic burden on the host society (Van Baalen and Mobjörk, 2018). The growing body of research on the topic uses a variety of methodologies, statistical approaches, data sources[5], and geographic perspectives[6], making comparison of the often conflicting results and the quantification of the link difficult (von Uexkull and Buhaug, 2021). Moreover, although attention has grown, there is a lack of projection studies estimating the long-term impacts of climate change on conflict risk, with the analysis of Witmer et al. (2017) representing an important effort in this direction (de Bruin et al., 2022). On the other hand, there is a growing number of models on the potential long-term impacts of climate change on agricultural and economic production (Deutsch et al., 2018; Murakami and Yamagata, 2019), as well as short-term climate-conflict prediction models (Hegre et al., 2022). Through qualitative and quantitative methods, the evidence for Sudan and South Sudan suggests that variations in the geographical distribution of water and vegetative resources (De Juan, 2015), and temperature anomalies (Maystadt et al., 2014a), are associated with the risk of violent conflict. Olsson and Siba (2013) show that militia attacks are more common in villages near floodplains, while, according to Sosnowski et al. (2016), the dry season and the reduced water flow from the Victoria Lake correspond to an increase in violent clashes between the Dinka and Nuer ethnic groups. Despite the increased attention on this region (Assal, 2006; Chavunduka and Bromley, 2011a; Leff, 2009; Rowhani et al., 2012), the relationship between climate variations, population dynamics, conflict and organised violence remains rather complex, with quantitative analyses at the sub-national level often yielding inconclusive results on the significance and causality of the link, and the mechanisms underlying the nexus remaining largely overlooked (Eberle et al., 2020).

Furthermore, recent sub-national studies have examined the relationship from the perspective of urbanisation, showing that climate impacts social unrest and clashes in urban environments and highlighting how migration, urbanisation, and unrest are interlinked (Koubi et al., 2021). While the spatial dimension of conflict is a key component of current conflict studies, no rigorous sub-national empirical research is available linking the location of conflict with urbanization, population density, and climate-induced migration across different areas of Sudan and South Sudan. Our study therefore seeks to provide further quantitative insights into the climate change-population-conflict link, the local conditions that may favour the association, as well as an exploration of the link in both urban and rural contexts of the two countries. An analysis of the causal mechanisms underlying the relationship

[2]https://ec.europa.eu/clima/eu-action/adaptation-climate-change/eu-adaptation-strategy_en.

[3]See https://thinkhazard.org/en/.

[4]Source: Uppsala Conflict Data Program (UCDP) https://www.pcr.uu.se/digitalAssets/806/c_806526-l_1-k_ucdp_special_bulletin_sudan.pdf (Last accesed: 10 December 2021)

[5]See for example the UCDP's GED database (Pettersson et al., 2021) and the Armed Conflict Location and Event Dataset (ACLED) (Raleigh et al., 2010).

[6]As spatially and temporally referenced conflict data increasingly become available, research has shifted rapidly from national to sub-national approaches, addressing the climate-conflict nexus in fragile countries with varying environmental and vulnerability local conditions.

and the role of climate variations in relation to other important conflict drivers is beyond the scope of this study. In this vein, we follow the growing line of empirical studies on the link between climate variations and conflict conducted at the local level with geocoded data. Through the geographic location of organized violence events, combined with spatial data on climate anomalies and various population dynamics from a 0.5 degree grid resolution for Sudan and South Sudan, we estimate the association between local temperature and rainfall anomalies and the occurrence of lethal organized violence in the years between 1989 and 2015. In addition, we follow the new degree of urbanisation (DEGURBA) classification[7] to analyse the distribution of organised violence across the territory according to the level of urbanisation of each cell in the two countries, thus distinguishing a rural-urban dimension in the patterns of violence and assessing its link with climate anomalies. Overall, our results suggest a positive association between temperatures and precipitation anomalies, as well as population density, with organised violence. When we focus the analysis on the degree of urbanisation, we observe a higher incidence of the different types of violence in urban and densely populated areas, associated with positive temperature anomalies and positive net migration.

The rest of the report is organised as follows: Section 2 presents recent trends in conflict and organised violence events, as well as temperature and precipitation anomalies at the local level. Section 3 describes the demographic data used in the analysis. Section 4 explains the methodology adopted in this report. Section 5 shows the results. Finally, Section 6 discusses the main findings and concludes.

[7] https://ghsl.jrc.ec.europa.eu/degurba.php.

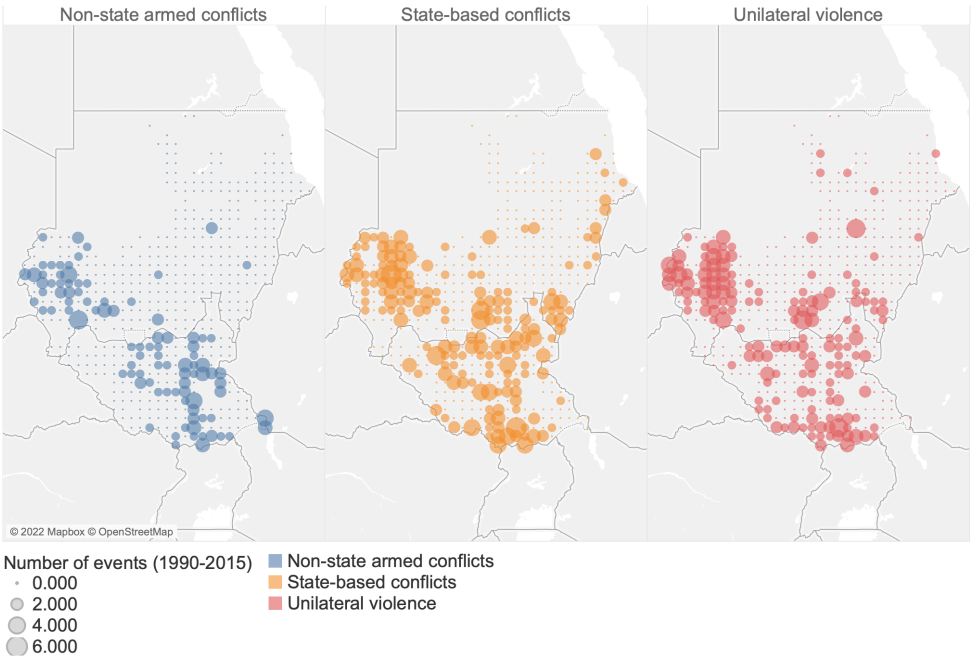
2 Organized violence and weather anomaly trends

We use the geocoded information on lethal, armed, and organised violence as provided by the UCDP Georeferenced Event Dataset (GED) Global version 21.1.[8] The data set contains events[9] classified into three categories of organised violence, namely state-based armed conflicts, non-state armed conflicts, and unilateral violence. State-based conflicts are violent events (such as civil wars), involving one state against another or against a non-state actor. Non-state armed conflicts includes communal conflicts, ethnic clashes, and conflicts between formally or informally organised rebel organisations. Finally, unilateral violence includes episodes of violence in which the state or a criminal organisation targets civilians.

We re-sampled the organized violence data set to the same spatial resolution of the climate and demographic data, which were stored in a 0.5x0.5 degree spatial grid covering the entire study area. Each violent event has been assigned to a unique cell of the grid, based on its proximity to the closest cell centroid. Doing so made it possible to work with a uniform spatial domain, thus allowing a direct comparison between the various features.

Figure 1 shows the geographical distribution of the number of events for the three types of organised violence over the entire period of analysis. About 14% of our sample recorded at least one violent event, with the three categories of violence often observed jointly in most cases. In the more recent years, community violence and one-sided violence have become the dominant categories in terms of number of events and casualties.

Figure 1: Number of organised violence events by type in Sudan and South Sudan, 1990–2015



Source: Our elaboration based on UCDP GED Global version 21.1

Table 1 shows the distribution of violence in rural and intermediate/urban cells. We analyse the presence or absence of (total) violence - we used a categorical variable equal to 1 if at least one conflict event occurred in the cell and 0 otherwise - and the type of violence, according to the degree of urbanisation in each cell. Of the total violence, 60% was recorded in urban and highly populated cells, compared to 40% in rural cells. The higher concentration of violence in urban and densely populated areas could be attributed to the concentration of economic and political resources and the

[8] `https://ucdp.uu.se/downloads/index.html#ged_global`.

[9] An 'event' is the incidence of the use of armed force by an organised actor against another organised actor or civilians, resulting in at least one direct death at a specific location and for a specific duration of time (Sundberg and Melander, 2013).

higher population competing for them (Raleigh and Hegre, 2009). When we disaggregate our data by type of violence and degree of urbanisation, we confirm the higher incidence of all forms of violence in urban areas. Regarding the intensity of violence (i.e. the number of violent events and the associated deaths), these data confirm urban areas as the most violent contexts.[10]

Table 1: Organized violence in Sudan and South Sudan by degree of urbanization, 1990, 2000, 2015

	Rural territory	Intermediate/Urban territory
Total Violence	40%	60%
State-based armed conflict	37%	63%
Non-state armed conflict	35%	65%
One-sided violence	43%	57%

Source: Our elaboration based on UCDP GED and Alessandrini et al. (2020).

The climate indicators used in this analysis are temperature and precipitation anomalies (Helman and Zaitchik, 2020; O'Loughlin et al., 2012). The indicators were taken from Petroliagkis and Alessandrini (2021) and McMahon et al. (2021) who used the Terrestrial Air Temperature (TAT) Gridded Monthly Time Series (Version 5.01) and the Terrestrial Precipitation (TP) Gridded Monthly Time Series (Version 5.01) datasets from the University of Delaware (Matsuura and Willmott, 2018). A temperature (precipitation) anomaly is defined as the deviation of the observed temperature (precipitation) at a location and time from the climate reference value of temperature (precipitation) at the same location, measured as an average value over a 30-year period. To create both measures, a historical average of temperature and precipitation (baseline) for the period 1980-2010 is calculated for each grid cell for Sudan and South Sudan. Then, a 5-year average is calculated for each sub-period (1990-1994, 1995-1999, 2000-2004, ...) between 1990-2015. The 5-year period anomaly is then computed as the difference between the mean value of the 5 years and the mean baseline observed in the same cell over the 30 years. For instance, for the grid cell *i* and over the period 1995-1999, the anomaly is the difference in temperature (or precipitation) in the same cell between the mean temperature (precipitation) for the sub-period compared to the baseline period. The highest recorded anomalies indicate that the temperature or precipitation values in a given cell-period are higher than their baseline 30-year average. Analyzing anomalies provides insight into whether the climate over a 5-year period was unusual compared to the reference period.

Figure 2 illustrates the temporal and geographical variation in climate anomalies, violent events and their associated casualties for the years between 1990 and 2015, aggregated over five-year averages.[11] Overall, there is an increase in positive temperature anomalies over time, with the highest values (about 1.7 degrees higher than the average) observed in the central and western part of the region and close to the extremely arid and desert areas of northern Sudan. The variation in rainfall anomalies follows a slightly different trend, with stronger negative anomalies (i.e. less rainfall than normal), in southwestern South Sudan, and stronger positive anomalies (more rainfall than average) in Sudan. We can graphically identify an overlap of the areas affected by violence (marked in grey in the map series in Figure 2), with the areas denoting regions of temperature anomalies and, to a lesser extent, with the areas denoting regions of rainfall anomalies. Positive temperature anomalies and victims of violence have increased in recent years, showing some overlap in their spatial distribution.

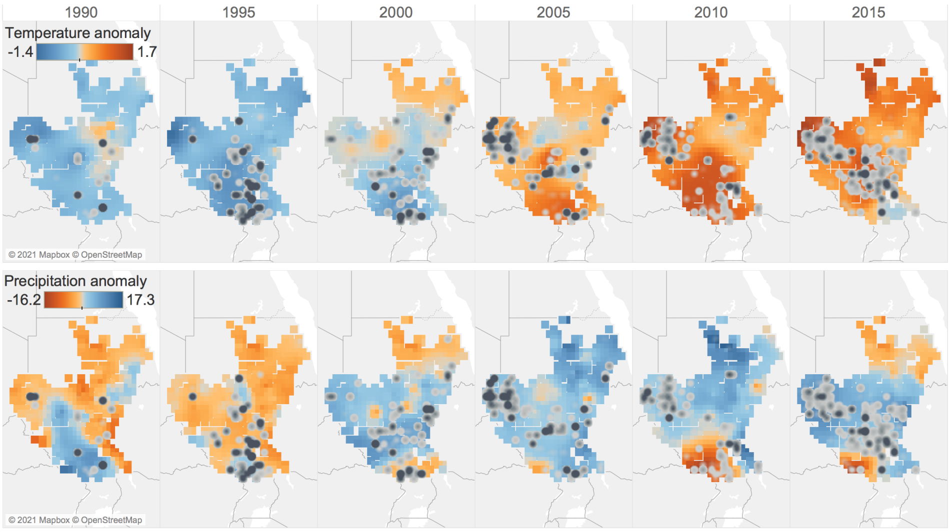
3 Demographic data

In addition to the climate anomalies used as the main explanatory variables in the regression analyses, we employ net migration, population density and the degree of urbanisation as demographic controls at the cell

[10] Data on the level of urbanisation are available only for the years 1990, 2000, 2015.

[11] Our data set covers about the 87% of the territory of South Sudan and a smaller proportion (58%) of Sudan, due to the presence of the desert.

Figure 2: Change in temperature and precipitations anomalies, conflict events and deaths (1990-2015)



Source: Our elaboration based on UCDP GED, Alessandrini et al. (2020) and Petroliagkis and Alessandrini (2021)

level. Net migration in each cell is the difference between the number of immigrants and emigrants in a given area over a five-year period, based on recent estimates by Alessandrini et al. (2020). In estimating net migration, the authors apply an indirect population estimation technique, combining population data from different statistical sources at a spatial resolution of 0.5 by 0.5 degrees, and with a global coverage for the period between 1975 and 2015.

Data on population density and degree of urbanisation are taken from the Global Human Settlement Layer (GHSL) spatial population data set developed by the Joint Research Centre (JRC). Each area of 0.5 by 0.5 degrees of resolution is classified as urban or rural following the degree of urbanisation classification (DEGURBA) and based on a combination of geographical contiguity criteria and a minimum population threshold applied to grid cells of 1 km^2.[12]

4 Regression analysis

We merge data on organized violence events with climate and demographic variables for each cell of the spatial grid in Sudan and South Sudan to examine the correlation of these events during the years 1990-2015. Following the approach found in the recent literature (Eberle et al., 2020; Vesco et al., 2021), we set our dependent variable as a binary indicator of the occurrence of any conflict and violence event for each grid cell.[13] Anomalies in precipitation and temperature, indicating the deviation observed in a 5-year period from the long-term average observed in the same cell, are the control climate variables in the analysis (Dell et al., 2012; Harari and La Ferrara, 2018). We also introduce the quadratic term of the climate anomalies to account for potential non-linearity in the climate-conflict association, as already done in Maystadt et al. (2014b). A positive sign of the quadratic weather term indicates a greater net effect than a linear one, i.e. conflict risks tend to increase more as the value of weather anomalies increases.[14]

The demographic variables capture the population density and the level of urbanisation of each cell and aim to test their association with the patterns of local violence. The net migration balance - lagged by a 5-year period - is introduced to test whether changes in mobility may influence the risk of violent clashes (Van Baalen and Mobjörk, 2018).The net migration variable is lagged by the reference period of time (5 years), to reflect the possible effects of past migration on violence and to mitigate endogeneity that may result from the relationship. It should be noted that through this variable it is not possible to identify the source or destination of migration

[12]More precisely, the cell is classified as rural if the population share in the cell is equal to or lower than the average African share of rural population. It is set as a dummy variable equal to 1 if the cell is rural and 0 otherwise. For more details, see the link `https://ghsl.jrc.ec.europa.eu/degurba.php`.

[13]The binary dependent variable jointly considers the presence of at least one of the three forms of violence. Analyses are also conducted on each form of violence separately, as well as on a continuous variable representing the number of events of any type of violence in each cell.

[14]See Schlenker and Roberts (2009a) on the non-linear and local effect of climate on agricultural income as an incentive to conflict and Dell et al. (2014) on modelling non-linear effects in the climate-economy literature.

flows, nor to assess whether migration in one cell is driven by climatic or security conditions in another cell or by urbanisation. Finally, we check for the serial correlation of conflict by including time lags of the dependent variable in the model (Harari and La Ferrara, 2018). We estimate a least squares model with fixed effects per grid cell and per country, to control for unobserved, time-invariant spatial features that may bias the association, and with robust standard errors clustered at the country level.

5 Results

Table 2 presents the results of the regression models on the occurrence of any conflict and violent event. The intensity of the anomalies significantly correlates with the increase in lethal and organised violence at the sub-national level (Column 1). In particular, the results show that temperature anomalies positively and significantly correlate with the risk of conflict. The coefficient of the quadratic term of the anomalies also suggests that higher temperatures and precipitation have the potential to exacerbate local violence.[15] The association between precipitation anomalies and conflict events is, however, less robust than that of temperature.

Population density is introduced in Column 2 and positively correlates with the risk of violent events. More densely populated areas are potentially more prone to violence, while violent clashes are rarer in less populated areas. This result is potentially in line with the argument that the emergence of conflicts is attributable to a large population competing over scarce local resources (Collier and Hoeffler, 2004; Raleigh and Hegre, 2009). Similarly, net migration is positively correlated with violence (and only slightly), as shown in Column 3, likely consistent with qualitative evidence supporting a link between increased environmental migration, declining rainfall and clashes between pastoralists and farmers (Chavunduka and Bromley, 2011b), as well as drought, environmental degradation and ethnoreligious conflicts in Sudan (Lee, 1997). The literature identifies climate-related migration as one of the possible mechanisms linking climate change to violence. The effects of climate events may influence temporary and seasonal migration as well as the movements of permanent migrants like cattle herders. According to Vesco et al. (2021), climate-induced negative shocks in agricultural production may influence net migration outflows, with rural workers resorting to migration as an adaptation strategy. Migration may increase the likelihood of conflict due to increased competition over economic and natural resources in host areas (Brzoska and Fröhlich, 2016), and increased ethnic tensions with host communities if migrants and natives belong to different ethnic groups (Bosetti et al., 2021; Burrows and Kinney, 2016; Hoffmann et al., 2021; Van Baalen and Mobjörk, 2018; Vesco et al., 2021). Taking a broader view, the role of population pressures on violence is increasingly being discussed, with the evidence indicating a positive and robust relationship between population size and violence (Fjelde and Østby, 2014). This is of particular concern for several African countries, including Sudan and South Sudan, which are expected to become more densely populated in the coming decades.[16]

In Columns 4 and 5, we further explore the climate-security nexus in rural and urban environments and thus divide our sample according to the level of urbanisation of each cell. For cells identified as rural, only higher values of climate anomalies correlate positively with local violence, while in intermediate and urban cells, the positive and significant coefficient of temperature anomalies is maintained. Net migration positively correlates with the risk of violence only in urban and intermediate cells while it has a non-significant coefficient in cells identified as rural. Current and projected demographic dynamics in these two countries, including urbanization, immigration to cities, and population natural growth in urban areas, could result in further pressure on the already limited resources, potentially affecting social stability in certain areas.

Results from Column 6 confirm a significant time dependency of conflict within cells. There is a significant temporal correlation in the proliferation of violence as past trends in violence influence the occurrence of new events in the same area and over time. Finally, in Column 7 we provide support for our results by using the number of events associated with any form of violence and observed in each cell as the dependent variable, denoting a certain intensity of violence. Estimates confirm that temperature anomalies, high rainfall variability, as well as the demographic variables of population density and net migration positively correlate with a higher number of events of organised violence. As a final check, we test the robustness of our results by accounting for spatial dependence and allowing for arbitrary spatial correlation, grouping neighbouring cells together into $\sim 200\, km^2$ clusters, similarly to McGuirk and Nunn (2020). It is important to note that conflicts can be explained by geographically clustered factors, which could overestimate the effects of climate change. As shown in Table 3 in the Appendix, our results remain similar when we adjust for spatial correlation.

The association between conflict and violence events and temperature anomalies is confirmed to be the strongest link in our estimates, in line with the current literature that identifies climate anomalies as a source

[15] We also tested this effect using different indicators of extreme temperatures (Petroliagkis and Alessandrini, 2021) and a specific threshold for extreme temperatures. In all cases, we find a strong positive correlation between the highest temperatures and violence.

[16] See McMahon et al. (2021) for an overview of possible alternative trajectories on total population size for different countries and their sub-national distribution projected over the coming decades.

Table 2: Regression results on Any Conflict Event and Number of Events

	(1) **Any Event**	(2) **Any Event**	(3) **Any Event**	(4) **Any Event - Rural**	(5) **Any Event - Middle & City**	(6) **Any Event**	(7) **Number Events**
Temp anom	0.090^{***}	0.100^{***}	0.102^{***}	0.27	0.194^{***}	0.104^{***}	0.802^{***}
	(0.27)	(0.026)	(0.031)	(0.066)	(0.070)	(0.030)	(0.308)
Temp anom (sq)	0.107^{***}	0.108^{***}	0.090^{***}	0.164^{*}	0.118	0.084^{**}	0.479
	(0.029)	(0.029)	(0.033)	(0.089)	(0.096)	(0.033)	(0.415)
Prec anom	0.002	0.002	0.003^{*}	0.001	0.004	0.003^{**}	0.020
	(0.001)	(0.001)	(0.002)	(0.005)	(0.005)	(0.002)	(0.017)
Prec anom (sq)	0.001^{***}	0.001^{***}	0.001^{***}	0.003^{***}	0.002^{***}	0.001^{***}	0.006^{***}
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.002)
Density		0.001^{***}				0.001^{**}	0.010^{**}
		(0.000)				(0.000)	(0.004)
Netmigr *(lagged)*			0.001^{***}	-0.001	0.001^{***}	0.001^{***}	0.001^{***}
			(0.000)	(0.004)	(0.000)	(0.000)	(0.000)
Any event *(lagged)*						0.061^{**}	
						(0.030)	
Num. Events *(lagged)*							0.216^{***}
							(0.063)
Constant	0.106^{***}	0.087^{***}	0.097^{***}	0.049	0.166^{***}	0.075^{***}	0.385^{*}
	(0.015)	(0.017)	(0.018)	(0.033)	(0.037)	(0.020)	(0.205)
Observations	$3,993$	$3,993$	$3,148$	735	594	$3,148$	$3,148$
R-squared	0.172	0.178	0.157	0.165	0.294	0.163	0.101
Number of id	547	547	500	332	246	500	500
Cell FE	YES	YES	YES	YES	YES	YES	YES
Country x Year FE	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

of conflict risk due to their negative impact on economic and human productivity, along with their value as a multiplier of threats (Graff Zivin and Neidell, 2014; Hsiang, 2010; Lobell and Burke, 2009; Schlenker and Roberts, 2009b).

6 Conclusions and Discussion

This report explored the association of organised violence and conflict with climate anomalies and demographic variables in Sudan and South Sudan during the years 1990-2015 using geocoded data. By exploring the relation between the location of violent events, climatic conditions, and demographic variables in the same areas, this analysis sought to contribute to quantitative studies on the patterns of local violence. Overall, our results indicate that an increase in climate anomalies, and in particular temperatures, correlates with an increase of organised violence. We also observe a positive correlation of organised violence with population density, positive net migration, and past events of violence at the sub-national level.

Our data show a higher incidence of all types of armed violence in urban and densely populated areas, with temperature anomalies, higher rainfall variability and immigration correlating with the risk and intensity of violence especially in urban and intermediate areas. While not backed up by the evidence in the paper, this positive association could be attributed to the competition for scarce natural and economic resources that is exacerbated in urban areas due to their high population density (Acemoglu et al., 2020).[17] It is worth noting that several African countries are experiencing rapid and steady urbanisation - also triggered by an increase in 'environmental' migrants - and accompanied by natural population growth, which potentially could increase the risks of social tensions and violence if not accompanied by a 'corresponding increase in productivity or investment in physical and human capital' (Acemoglu et al., 2020).[18] On the other hand, the inflow of young workers and increasing immigration to cities offer an opportunity to leverage the demographic dividend to boost economic growth and stability. More importantly, we believe it is crucial to examine the impact of population growth and change at the local level, as rural and urban populations in the same country can experience disparities in growth and structure, leading to diverse socio-economic outcomes.[19]

Overall, this analysis supports the link between climate stress and conflict, with extremes and variability in rainfall and temperature showing the potential to increase conflict risk. With a quantitative approach, this case study could complement qualitative research on climate change and violence in Sudan and South Sudan (Assal, 2006) as well as evidence exploring increases in climate change-induced migration as potential catalysts for conflict (e.g., between pastoralists and farmers) (Chavunduka and Bromley, 2011b; Lee, 1997). We recognise, however, that without a deeper analysis of the history of these conflicts, such analysis remains limited in its ability to identify how much (and whether) recent violence in Sudan and South Sudan is linked to climate change, as well as how these findings can be extended to other fragile contexts. Additionally, while the media cover the fighting in detail, we recognize that some of the reporting of violence may be biased towards densely populated areas, and under-reported in remote and low-density areas (Eck, 2012; Weidmann, 2016). For effective policy design (Koubi, 2019), we recommend expanding the analysis to a broader set of countries to facilitate statistical comparisons and reveal the causal mechanisms behind the links between climate change and organised violence, including impacts on household welfare and migration as an adaptation strategy, which could prevent any spurious correlations that might arise from the nexus.

At the policy level, this report emphasises the importance of keeping a local perspective when assessing demographic and climate trends as potential sources of instability and calls for context-specific solutions. Even if political and socioeconomic factors remain the primary drivers of violent conflicts within states and climate is not a direct cause of them, a deeper understanding of local communities and the distribution of climate change-related risks among vulnerable populations is critical to increase adaptive capacity, strengthen resilience and sustain stability.

[17] According to Lichbach (1995), rural areas that are sparsely populated are rarely plagued by violence, whereas those areas that are sufficiently populated are more likely to see violence, i.e. violence is more likely to occur if a certain level of population is present.

[18] According to Acemoglu et al. (2020) the effect of population growth on social conflicts is considerable for conflicts related to natural resources.

[19] See also `https://www.giga-hamburg.de/en/research-and-transfer/projects/population-growth-and-security-in-africa`.

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List of abbreviations and definitions

CLICIM Climate Change Induced Migration 2

GED Georeferenced Event Dataset 5

GHSL Global Human Settlement Layer 7

JRC Joint Research Centre 7

UCDP Uppsala Conflict Data Program 3

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Annexes

Annex 1. Allowing for Arbitrary Spatial Correlation with 200 km ^{2} clusters

Table 3: Regression results on Any Conflict Event and Number of Events allowing for arbitrary Spatial Correlation with 200 km^2 clusters

	(1) **Any Event**	(2) **Any Event**	(3) **Any Event**	(4) **Any Event - Rural**	(5) **Any Event - Middle & City**	(6) **Any Event**	(7) **Number Events**
Temp anom	0.093*	0.103**	0.105*	0.022	0.211**	0.107*	0.802***
	(0.050)	(0.049)	(0.060)	(0.074)	(0.091)	(0.058)	(0.308)
Temp anom (sq)	0.103**	0.103**	0.085	0.171*	0.095	0.080	0.479
	(0.045)	(0.045)	(0.051)	(0.091)	(0.084)	(0.052)	(0.415)
Prec anom	0.002	0.002	0.003	−0.000	0.005	0.003	0.020
	(0.002)	(0.002)	(0.002)	(0.004)	(0.005)	(0.002)	(0.017)
Prec anom (sq)	0.001***	0.001**	0.001***	0.003***	0.002***	0.001***	0.006***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.002)
Density		0.001***				0.001**	0.010**
		(0.000)				(0.000)	(0.004)
Netmigr *(lagged)*			0.001***	−0.001	0.001***	0.001***	0.001***
			(0.000)	(0.004)	(0.000)	(0.000)	(0.000)
Any event *(lagged)*						0.057	
						(0.035)	
Num. Events *(lagged)*							0.216***
							(0.063)
Constant	0.086**	0.076**	0.088**	0.041	0.176***	0.075*	0.385*
	(0.034)	(0.036)	(0.039)	(0.032)	(0.031)	(0.040)	(0.205)
Observations	3,957	3,957	3,121	732	587	3,121	3,148
R-squared	0.170	0.176	0.157	0.164	0.297	0.162	0.101
Number of id	542	542	495	331	243	495	500
Cell FE	YES	YES	YES	YES	YES	YES	YES
Country x Year FE	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

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