VULNERABILITY TO CLIMATE CHANGE AND COMMUNAL CONFLICTS: EVIDENCE FROM SUB-SAHARAN AFRICA AND SOUTH/SOUTH-EAST ASIA

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Vulnerability to climate change and communal conflicts: evidence from Sub-Saharan Africa and South/South-East Asia

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Abstract

This research work provides new evidence about the effect of vulnerability to climate change on the likelihood of communal violence, by sorting out regional-specific pathways. We focus on Sub-Saharan Africa and South/South-East Asia for the period 1995-2016, these regions being particularly exposed to climate effects and characterized predominantly by rain-fed agriculture and climate-sensitive economic activities. Relying on the ND-GAIN Vulnerability Index as a multidimensional measure for propensity of human societies to be negatively impacted by climate change, we found robust evidence that greater vulnerability is conducive to a higher risk of communal violence in Sub-Saharan Africa. On the other hand, in South/South-East Asia, results suggest that current climate variability, measured as rainfall deviations within the period, exerts a greater effect on communal violence outbreak than overall vulnerability to climate change. In both regions, greater access to productive means is associated to the reduction of conflict risk. Some policy implications were derived that suggest an integrated approach between climate policy-making and social stability efforts, given conditional effects of climate change over the likelihood of communal violence.

Keywords: communal violence; vulnerability; climate change; conflicts; Africa; Asia

JEL: D74, O13, Q54, Q56

Key policy insights

- A regional-specific approach should be preferred to derive consistent policy implications in the climate-conflict literature
- Greater vulnerability to climate change is conducive to a higher risk of communal violence in Sub-Saharan Africa during the period 1995-2016
- Most countries in Sub-Saharan Africa exceed the minimum level of vulnerability associated with a significant increase in the likelihood of communal violence, signaling the existence of a security issue
- In Sub-Saharan Africa reducing vulnerability to climate hazards through adaptation strategies make for more peaceful societies
- In South/South-East Asia rainfall variability impacts the risk of communal violence most likely due to deteriorating agricultural capacities and livelihood essentials

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1 Introduction

Over the past decade, a growing body of empirical literature has explored the climate-conflict nexus, unveiling multiple causal paths. While this distinct plurality of findings supports the urgency of further exploring the nexus, it also fuels criticism about the inconsistency of results (Koubi 2019). A convergence towards a robust climate effect over conflict risk is indeed far from being established (Bernauer et al. 2012, Buhaug et al. 2014, Salehyan 2014, Mach et al. 2019).

The study of the effects of rainfall anomalies exemplifies this inconsistency. Abundant rainfall is found to increase violent events in diverse contexts (Witsenburg & Adano 2009, Raleigh & Kniveton 2012), most likely by reducing the opportunity cost of recruitment and fighting. However, O'Loughlin et al. (2012) provides evidence that periods characterized by abundant rainfall are more peaceful, whereas drier periods show no effects. On the other hand, droughts seem to increase the risk of violent events (Fjelde & von Uexkull 2012), in support of the environmental scarcity argument. According to this approach, shortages of food, water or crops production might generate stress in institutional and economic settings, which can be translated into social instability, especially in agriculture-dependent societies.

Such heterogeneous results can be explained by the existence of multiple climate-conflict pathways, rather than a single causal chain, and qualitatively different conflict typologies (Nordkvelle et al. 2017). The findings about the climate-conflict nexus may also diverge since empirical studies focus on different kinds of organized violence, various geographical areas, and apply heterogeneous methodological approaches (Cappelli et al. 2020). While several studies are based on a cross-sectional approach accounting for non-climatic factors (O'Loughlin et al. 2014), others stress the importance of providing self-comparison among specific locations across time to obtain reliable results (Hsiang & Burke 2014). A comprehensive discussion about this issue is provided in Helman et al. (2020).

Although a direct causal connection between climate change and conflict is hard to establish, there is a much larger consensus about the existence of an indirect transmission channel through which climate conditions feed instability and socio-political violence (Koubi 2019). In particular, it is argued that the effects of a changing climate deeply impact on production systems and socio-economic structures hindering local development (Caruso et al. 2016), stimulating human displacement and increasing the probability of inter-group conflicts (Hodler & Raschky 2014, Hegre et al. 2016), especially in the case of social marginalization. Within this scenario, population growth and weak institutional settings - common characteristics of low income countries - can boost grievances and reinforce multidimensional inequalities, amplifying the negative impacts generated by economic disruptions and, thus, making violence outbreak more likely.

This study fits this branch of literature and enriches the debate by enlarging the perspective of the analysis and highlighting the role of vulnerability to climate change. In fact, climate change is already having a substantial physical impact at a local level in regions across the world. However, the socioeconomic impact generated is nonlinear as susceptibility to climate hazards is diversified between countries and subsequent context-based effects are likely to occur. This variance is conducive to different adverse outcomes in food security, health, economies and ecosystems (Burke et al. 2018).
We therefore consider the magnitude of the effects produced by climate change as largely depending on the degree of vulnerability to climate hazards. A complex intertwining of factors ranging from geographic location and environmental features to social and economic conditions, including irregular development processes (Eriksen & O'brien 2007), defines to what extent a country is vulnerable to climate hazards (IPCC 2014). Based on the research outcomes on how natural hazards affect human structures and communities (Janssen et al. 2006), the concept of vulnerability to climate change is widely applied in the climate literature (O'Brien et al. 2007). The Intergovernmental Panel on Climate

Change (IPCC) Third Assessment Report (TAR) outlines the concept of vulnerability to climate change as a function of three components: exposure, sensitivity, and adaptability (McCarthy et al. 2001). The three components reflect different dimensions of vulnerability: *exposure* refers to the likelihood of a hazard occurring; *sensitivity* reflects the degree of susceptibility to the hazard, and *adaptive capacity* describes the ability to cope with the hazard and the consequences that are likely to be generated (Weißhuhn et al. 2018). We argue that analysing the vulnerability to natural hazards allows for capturing indirect and conditional effects of climate change on conflict risk.

Since climate change is likely to rise uncertainty over access to natural resources - especially land, water and forests - and to alter climate-sensitive livelihoods, we narrowed the scope of the analysis by focusing on organized violence involving those groups who are more vulnerable to such effects, namely communal groups. These groups, whose membership is mainly based on religious, ethnic or linguistic identity, are usually engaged in traditional economic systems of production, such as subsistence agriculture and pastoralism. This allows us to test our hypothesis on a homogeneous group of armed events - expression of communal violence - and suggest reasonable underlying casual mechanisms. This methodological choice is consistent with empirical literature about the climate-conflict nexus (among others, see van Weezel (2019), Nordkvelle et al. (2017). A communal conflict is conceived as a deadly armed occurrence between two informally organized armed groups neither of which is the government of a state, and defined by a collective identity, for example, ethnic lines. (Sundberg et al. 2012). Communal violence is likely to occur as a result of increased inter-groups competition over means for livelihood, resources and local power, especially in the case of socioeconomic marginalization of specific groups (Hillesund 2019). For example, inter-community violence is likely to erupt when different groups base their economic systems on the same livelihood requirements and the access over scarce resources become more problematic (Homer-Dixon 1999). Supply-induced scarcity triggers competition over renewable resources, such as grazing land and water, fuelling fights over livelihood essentials. At the same time, scarcity can also shove groups into searching for resources in other territories, potentially igniting new clashes with other groups (Reuveny 2007). Although communal violence tends to be clustered in space and time, its incidence might destabilize entire regions (Balestri & Maggioni 2017), expand across borders (van Weezel 2019), and trigger violence escalation in given areas.

This study explores how variations in vulnerability to climate hazards affect the risk of communal violence, accounting for environmental and socio-economic factors which might influence this relationship. To overcome the narrowness of a "one-fits-all" approach and to discover possible regional patterns, we analysed Sub-Saharan Africa (henceforth: SSA) and South/South-East Asia (henceforth: S-SEA), these regions being particularly exposed to the effects of climate change and characterized predominantly by rain-fed and climate-sensitive agriculture. Nevertheless, it is worth underlining that S-SEA represents an under-studied area in the climate-conflict nexus (Wischnath & Buhaug 2014), and that this paper enriches the empirical literature about the region.

We found evidence for a clear geographical pathway where vulnerability to climate change increases the risk of communal conflict in Sub-Saharan Africa; in South/South-East Asia, instead, climate variability - measured by rainfall deviations - seems to play the major role. Noticeably, a greater access to productive means within traditional economic systems reduce the likelihood of communal violence in both regions.

2 Methods and data description

While taking into account factors which might impact on traditional livelihoods, we explore the relationship between vulnerability to climate change and events of communal conflict in Sub-Saharan Africa and South/South-East Asia in the period 1995-2016.

The decision for focusing on the geographical scope of this study in such regions is based on the empirical evidence that they share common traits in some meaningful dimensions for the purpose of this study, although they show distinct socio-economic characteristics. On one hand, in fact, SSA and S-SEA are both subject to communal violence and they are classified particularly vulnerable to climate change (Schleussner et al. 2018). Vulnerability to climate change is unevenly distributed across the world, due to both climatic and non-climatic factors, such as inequality. On the basis of the 1.5°C warming limit established in the Paris Agreement, Schleussner et al. (2018) identify key vulnerability areas by overlapping climate hot spots with the Multidimensional Poverty Index (MPI). Sub-Saharan Africa and South/South-East Asia are among those identified. Moreover, both regions are characterized by widespread poverty, dependence on rain-fed agriculture, and a history of violence. We argue that these characteristics outline broad similarities which allow for analyzing the determinants of communal violence across this geographical area.

On the other hand, the source of vulnerability to climate hazards might be embedded in context-specific features whose differences can contribute to uncovering distinct causal pathways of communal violence. In other words, significant variations in both vulnerability levels and socio-economic structures across countries also exist within the two regions, allowing us to better understand the patterns of violence outbreak.

Further, as Hendrix (2017) points out, scholarly attention has been devoted to analyze the African context more particularly in the climate change literature. This operational choice makes sense to the extent that in SSA climate change is likely to produce massive physical, economic, and social impacts due to the primacy of agricultural livelihoods and limited resources for investment in adaptation. With few exceptions, a similar geographical bias characterizes the literature exploring the climate change-conflict nexus (Wischnath & Buhaug 2014), and limits the generalizability of results.

To perform the analysis, we structured a country-year panel data including information abut the occurrence of events of communal violence, countries' vulnerability to climate change and other factors connected to productive systems. The list of countries included in the analysis, complete with details about incidence of communal violence and vulnerability scores, is provided in Table A3 and Table A4 in the Appendix.

To substantiate our research hypothesis, the first stage of analysis is devoted to exploring the correlation pattern between the incidence of communal violence and vulnerability to climate hazards across the two selected regions.

As a second step, we developed a statistical model of risk of communal violence. The unit of analysis is the country-year observation. The likelihood of events of communal violence is estimated by a random-effect probit model as a function of vulnerability, forest share, agricultural land *per capita*, rainfall anomalies, GDP growth and previous occurrence of communal violence. To control for socio-environmental heterogeneity, all specification models incorporate sub-regional fixed effects defined according to the United Nations geo-scheme for Africa and Asia. Standard errors are clustered at country level.

In addition, we tested the main outcomes against a set of robustness checks: first, we changed the estimation technique applying a probit link function including time polynomials to model time dependence; second, we re-estimated the models relaxing the constraint of sub-regional and time fixed effects. Results confirm the validity of our main findings (see Table A6 in the Appendix).

2.1 Dependent variable: communal violence

Communal violence occurs when non-state groups that are organized along a shared collective identity line - such as ethnic or religious affiliations and kinship ties - are involved in armed events. To provide a measure of occurrence, we relied on data gathered from the UCDP Geo-referenced Event Dataset (UCDP GED) (Sundberg & Melander 2013, Croicu & Sundberg 2015) and the Non-State Conflict Dataset to identify all violent events recognizable as expression of communal violence (Sundberg et al. 2012). In the UCDP-GED, all events that result in at least one fatality - within conflicts having 25 annual deaths as a threshold - are recorded along with information about the groups involved and the organizational level of the warring sides. We selected all armed events belonging to non-state conflicts which correspond to the definition of communal violence by including those events where groups, not permanently organized for combat, organize themselves along shared common identity lines to engage in fighting. In this paper, we interchangeably use the terms communal conflict and communal violence to indicate an armed event corresponding to the definition provided above. For the period of analysis, UCDP GED reports 2171 events of communal violence in Sub-Saharan Africa, whilst 469 events took place in South/South-East Asia. The outbreak of individual events of communal violence is operationalized as a dichotomous variable, taking the value of 1 if an event is recorded in a given country-year, 0 otherwise.

The temporal occurrence of communal violence outlines very distinct realities across the two regions: whilst SSA appears particularly affected and shows a relatively high number of armed events attributable to communal conflicts, S-SEA is undoubtedly less prone to this kind of socio-political instability (Figure 1). Conflicts between the Turkana and Pokot pastoralist communities in northern Kenya as well as farmer–herder conflicts in the Sahel belt in Nigeria, just to mentions a few, are well-known inter-communal clashes fed by ethnic identity. This prevailing incidence made Sub-Saharan Africa the most studied area in terms of communal violence (see, for example, Fjelde & Østby (2014), Eck (2014), van Weezel (2019)).

Asian countries, nevertheless, report multiple and deadly events, although quite limited in number and geographical scope, which deserve to be explored more extensively. For instance, the proliferation of ethnic insurgent groups in north-eastern India in the 1990s led to destructive and widespread conflicts mainly fought on land and identity issues, and generated thousands of fatalities and internally displaced people (Haokip 2013). Groups in Asia, just the same as in Sub-Saharan Africa, have clashed over land and land-related resources. Environmental degradation, expropriation of communal land, and unequal access to livelihoods represent just some of the processes creating tension between communities in South/South-East Asia (Wilson 2017).

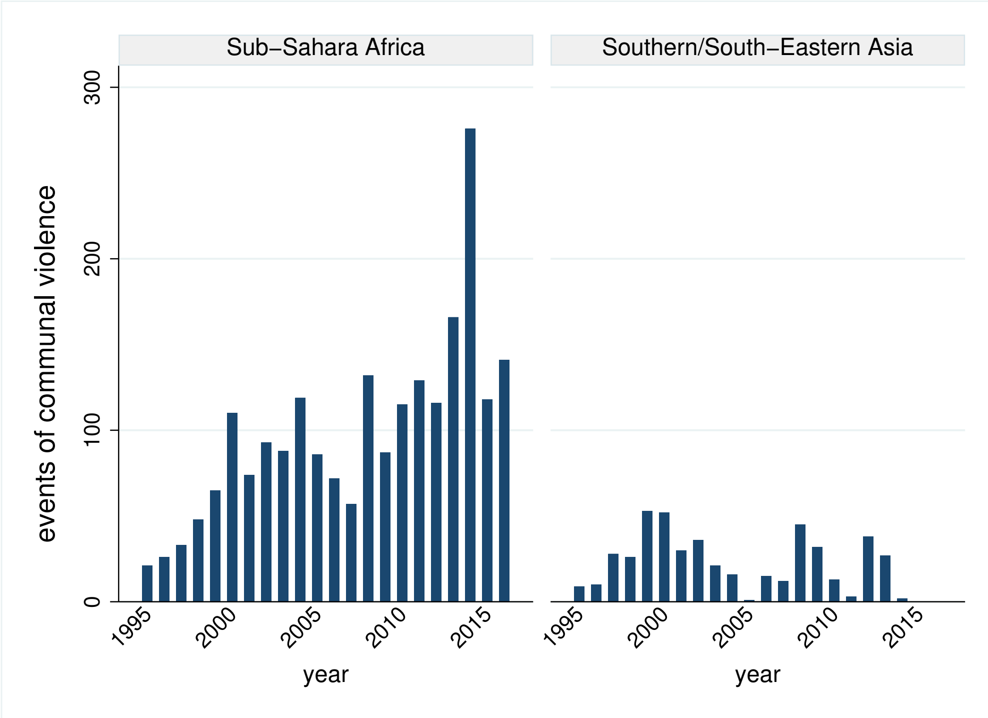

Figure 1: **Occurrence of events of communal violence.** Yearly number of events of communal violence reported in Sub-Saharan Africa and South/South-East Asia (1995-2016). See Table A3 and Table A4 in the Appendix for country-specific information on communal violence occurrence.

2.2 Explanatory variables: vulnerability to climate change

Vulnerability refers to what extent a society is susceptible to harm from exposure to environmental stresses and social changes, and its lack of skill in adaptation strategies. (Adger 2006). It is therefore a multidimensional and dynamic phenomenon whose measurement requires a comprehensive approach. We decided to rely on the quantitative measure of vulnerability to climatic hazards elaborated by the The Notre Dame Global Adaptation Initiative (ND-GAIN) which includes both social and ecological components across multiple life-supporting sectors, and describes the comparative resilience of countries to climate change (Chen et al. 2015). The ND-GAIN Vulnerability Index is an established metric used by scholars and policy makers to inspect challenges and adaptive opportunities associated with climate uncertainty in different domains. Recent studies applying the index refer to a wide spectrum of subjects including the effects of climate-related vulnerability on agricultural yields (Epule et al. 2017), adaptation investment decision-making (Chen et al.

2018), global tourism (Scott et al. 2019), sovereign borrowing (Beirne et al. 2021), and firms' cost of capital and access to finance (Kling et al. 2021).

The ND-GAIN index provides a quantitative assessment of vulnerability intended as the propensity or predisposition of human societies to be negatively impacted by climate hazards. The index ranks countries on the basis of their performance on 36 indicators referring to six distinct sectors (namely, food, water, health, ecosystem services, human habitat and infrastructure), and measuring the three cross-cutting dimensions of exposure, sensitivity and adaptive capacity. The selection of both dimensions and sectors is consistent with those identified by the United Nations Intergovernmental Panel on Climate Change (IPCC) (Edmonds et al. 2020). Each sector score is tracked through multiple indicators to envisage a broad set of social and geopolitical factors which are likely to shape the vulnerability of a society to climate change. The overall vulnerability index score is the unweighted arithmetic mean of the six sectors scores, normalized on [0,1] range with higher values expressing greater vulnerability. Table A5 in the Appendix illustrates the index structure by providing details about the indicators used in each life-supporting sector.

On average, vulnerability to climate change is fairly high in both regions (Figure 2). Sub-Saharan Africa appears particularly susceptible to the effects of a changing climate, with an overall average score of 0.5423. Higher score values are reached in the Sahel and the central-eastern area, although large variations exist. In regard to the S-SEA region, the overall vulnerability score is slightly lower (0.5109), but in this case, too, we found a large country-specific variance. In particular, southern countries - such as Pakistan, India, Bangladesh - report higher vulnerability as compared to other countries within the same region.

Looking at yearly changes in the vulnerability index score, we noticed a steadily higher number of countries experiencing a reduction in vulnerability as compared to those facing an increase in both regions (Figure 3). Although this pattern sounds highly encouraging, the number of countries with deteriorating conditions stay high and vulnerability score levels remain alarming in absolute terms, especially in Sub-Saharan Africa.

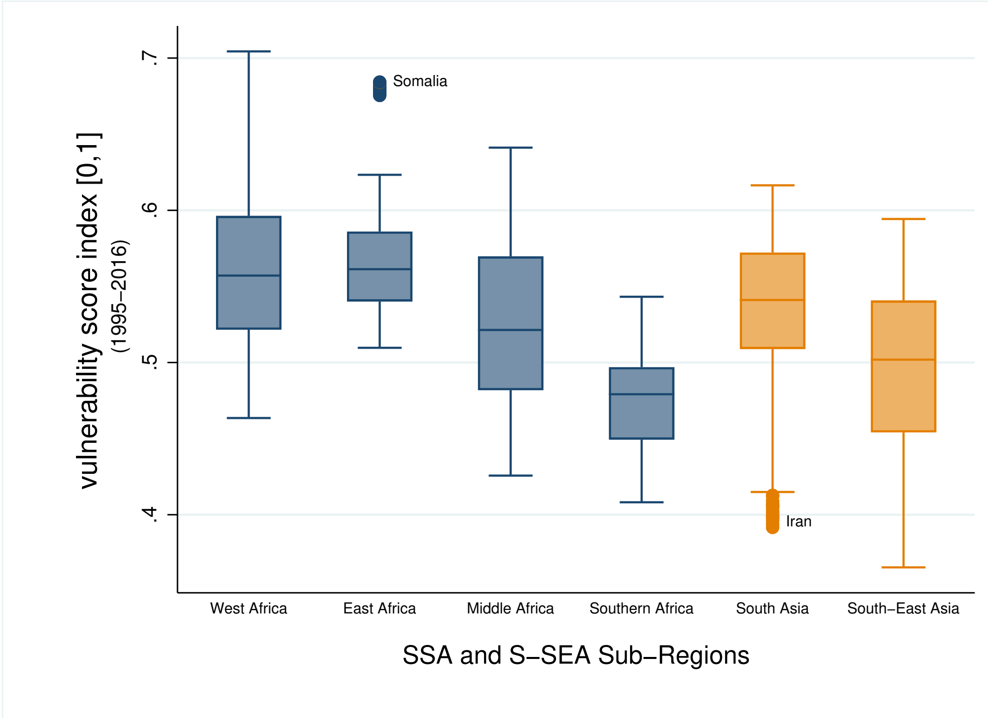

Figure 2: **Vulnerability index scores.** Median, 1st and 3rd quantiles of vulnerability index by sub-region. Whiskers indicate 95% confidence interval. See Table A3 and Table A4 in the Appendix for country-specific information.

Considering the whole period of analysis (1995-2016), 14 countries in SSA (out of the 46 included) increased their level of vulnerability, with an average worsening of 1.7% in the index score. The Gambia and Central African Republic are the countries whose vulnerability increased the most. In both cases, a deficient agricultural capacity (which reflects a country's ability to acquire and deploy agriculture technology) largely determined the worsening. It also highlights the critical role played by agrarian systems and food production in making societies more resilient to climate change (Buhaug et al. 2015).

In regard to S-SEA, almost all countries reduced their vulnerability to climate hazards during the period of observation (-2.5% on average). Nevertheless, absolute values remain problematically high even in countries whose vulnerability score considerably decreased, such as Buthan and Cambodia. In this latter case, for example, a very low adaptive capacity, associated with an ever present prevalence of poverty, and the geographic location make the country particularly exposed to the effects of climate change.

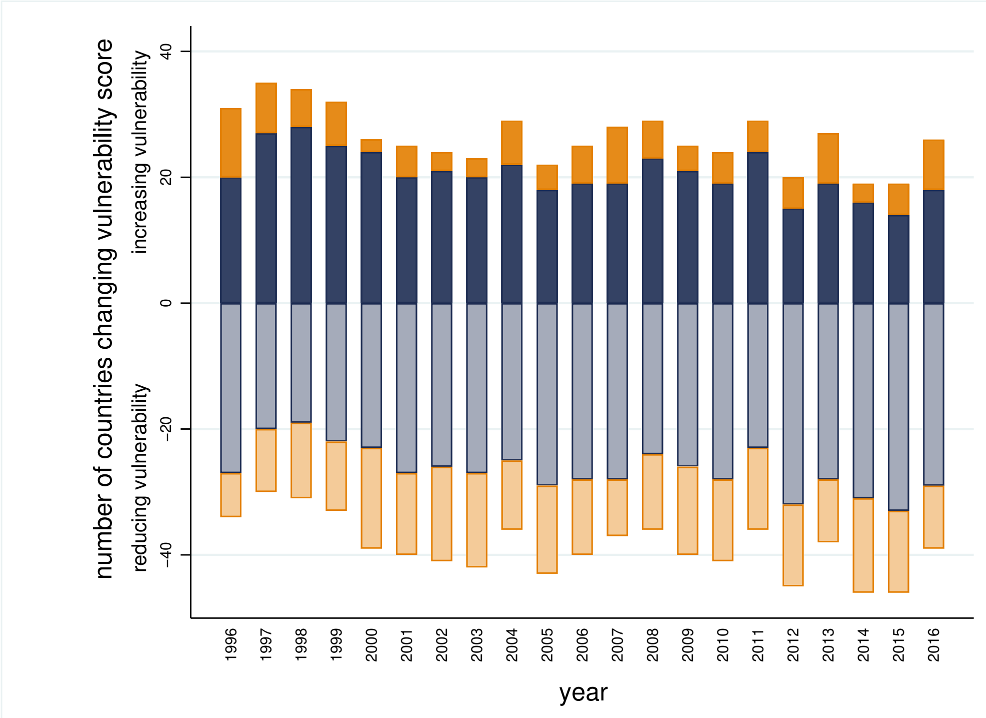

Figure 3: **Number of countries experiencing a change in the vulnerability index, by year.** Upper bars illustrate the total number of countries reporting a positive yearly variation of the index score (= increasing vulnerability, darkest shades). Lower bars illustrate the total number of countries experiencing a negative yearly variation of the score (= reducing vulnerability, lightest shades). In each bar, the blue section refers to Sub-Saharan Africa, whereas the orange section refers to South/South-East Asia.

To account for a possible endogenous relation between vulnerability to climate change and conflict (Buhaug & von Uexkull 2021), we temporally lagged the index score by one year in the empirical analysis.

2.3 Other controls

In addition to a country's vulnerability to climate change, other factors are likely to contribute to communal violence outbreak. In accordance to the purpose of this research, we argue that changes in forest and agricultural areas, rainfall anomalies and economic performance may impact on conflict propensity given the overall vulnerability level of a country to natural hazards. We therefore include additional controls accordingly.

Globally, 1.6 billion people (nearly 25% of the world's population) rely on forests for their livelihoods, especially those living in extreme poverty (FAO & UNEP 2020). Besides being essential for so many social groups, forests help stabilise the climate, regulate ecosystems, protect biodiversity, and are integral part in the carbon cycle. We therefore included a measure of forests (*forest share*) as the share of the country's territory covered by forests to control for deforestation (and conversely afforestation) at country level. We gathered data from the UN Food and Agriculture Organization (FAOSTAT 2020).

Economic systems of communal groups are often based on agricultural activities and pastoralism. Having access to natural resources is a major determinant for their livelihoods, to the extent that clashes between farmers and herders constitute frequent cases of communal violence. We, therefore, computed a measure of *per capita* agricultural land (*agric pc*) - including cropland and pasture land - to control for potential individual access to livelihood essentials. The database FAOSTAT provides annual information about country agricultural surface, while we gathered population data from the World Development Indicators (WDI) of the World Bank to elaborate the control variable. This measure is temporally lagged to avoid reverse causality since population level is affected by the conflict outcome.

Although results about the causal relation between rainfall anomalies and the risk of civil conflict are mixed, several studies suggest a connection between precipitation variability - primary manifestation of a changing climate - and communal violence (among others, Witsenburg & Adano (2009), Fjelde & von Uexkull (2012), Raleigh & Kniveton (2012), Detges (2014), van Weezel (2019)). Increasingly erratic weather patterns undermine the functioning of agro-ecological systems and might deteriorate socioeconomic conditions by increasing production risks and exacerbating livelihood insecurity (Buhaug et al. 2015). While the vulnerability index embraces a comprehensive measure of current and foreseen water availability to measure the degree of susceptibility of human societies to climate change, short-term climate variability - such as observed precipitation anomalies - are unaccounted for. As a consequence, we included a control variable measuring the deviation of yearly precipitation as compared to to the average total precipitation level over the period (1995-2016) for each country, expressed as z-score. We used data from the Climate

Research Unit (CRU TS) gridded historical dataset - retrieved through the World Bank Climate Change Knowledge Portal (CCKP) - to construct the control variable. In order to increase readability of results, we decided to distinguish between positive and negative deviations - both used in absolute terms (namely *neg rainfall dev* and *pos rainfall dev*) - as in Fjelde & von Uexkull (2012).

Among the sturdiest correlates of civil conflict, poor economic performance stands out as the primary trigger of violence outbreak. Weak socio-economic development undermines economic dependency relations between different social groups, increasing grievances and reducing the opportunity-cost of joining a rebellion (Collier & Hoeffler 2004, Miguel et al. 2004). The vulnerability index, however, might be significantly correlated with GDP levels by construction, since it includes several indicators of adaptive capacity which mainly depend on the country's economic performance (Kling et al. 2021). To overcome endogeneity issues, we relied on including GDP growth rate - temporally lagged - to account for the overall economic trend regardless the actual economic capacity achieved by a country (*GDP growth*). Original data are gathered from the World Bank WDI.

Lastly, we included a further covariate to control for prior experience of communal violence, the history of violence being a major determinant of conflict incidence.

Data source and descriptive statistics of the main explanatory variable and the other covariates are summarized in Table A1 and Table A2 in the Appendix.

3 Results and discussion

This section illustrates the results of the analysis. To the best of our knowledge, this is the first systematic attempt at analysing the effect of vulnerability to climate change - measured by the ND-GAIN index - on the risk of communal violence, thus we cannot compare the findings to reference literature.

The first stage of analysis is devoted to qualitatively exploring meaningful connections between communal violence and vulnerability to climate change. Descriptive insights suggest some consistent regional pathways, although communal violence erupted in diversified climatic and socio-economic contexts.

Looking at SSA, a higher number of events of communal conflicts occurred where vulnerability to climate hazards is higher (Panel (B) in Figure 4). In such a situation, vulnerability levels among country/year observations with at least one event of communal conflict significantly differ from those not subject to communal violence (prob $|z| < 0.001$). This finding supports our research hypothesis suggesting a detrimental association between vulnerability and social stability, most likely through the increase in the precariousness of livelihood means.

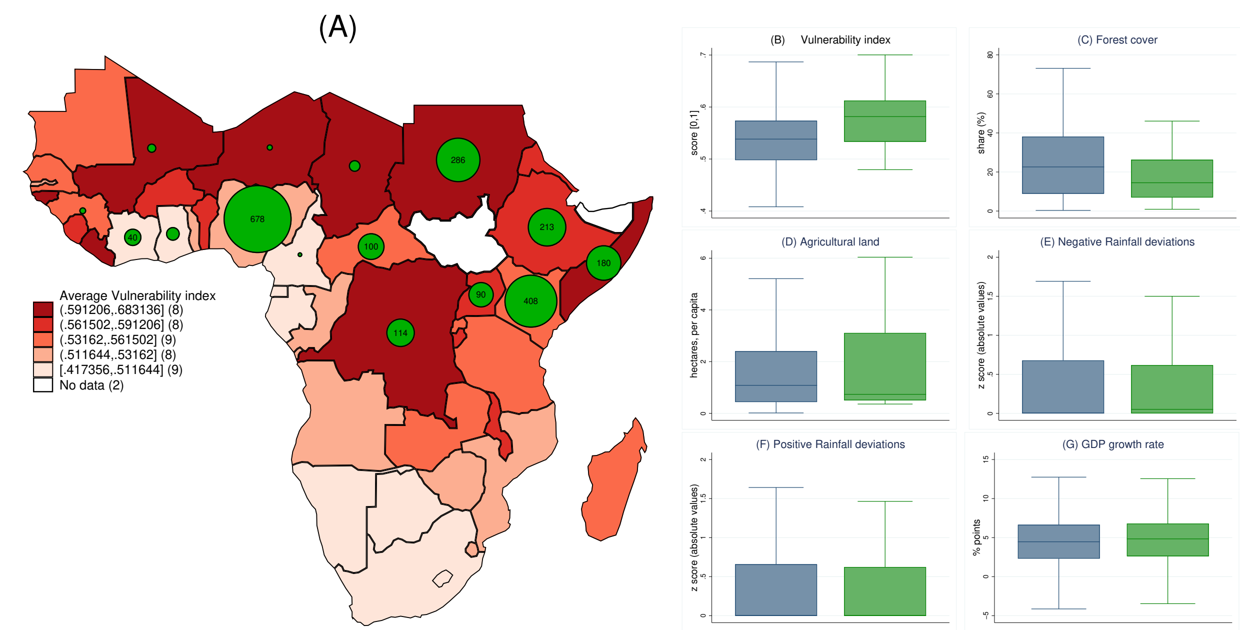

Figure 4: **Vulnerability index and incidence of events of communal violence in Sub-Saharan Africa.** Left-hand panel **(A)** illustrates average vulnerability country levels over the period 1995-2016 and the occurrence of events of communal violence. Darkest shades refer to greater vulnerability and green circles are proportional to the absolute number of events. Box-plots on the right-hand panel show median, 1st and 3rd quantiles of **(B)** vulnerability index, **(C)** forest share, **(D)** agricultural land *per capita*, **(E)** and **(F)** rainfall deviations, and **(G)** GDP growth rate for respectively countries not characterized by communal conflicts (blue) and experiencing communal violence (green). The two groups are significantly different in **(B)**, **(C)** and **(D)** at prob $|z| < 0.001$.

In S-SEA the same correlation pattern appears weaker (Figure 5): for example, the case of Indonesia, where a relevant number of armed events occurred despite a relative low level of vulnerability (.4637, on average) suggests a less straightforward association. Interestingly, countries characterized by communal violence show a significant lower amount of agricultural land *per capita* (|z| <0.001), suggesting a possible explanatory pathway for understanding the incidence of communal violence in a given country.

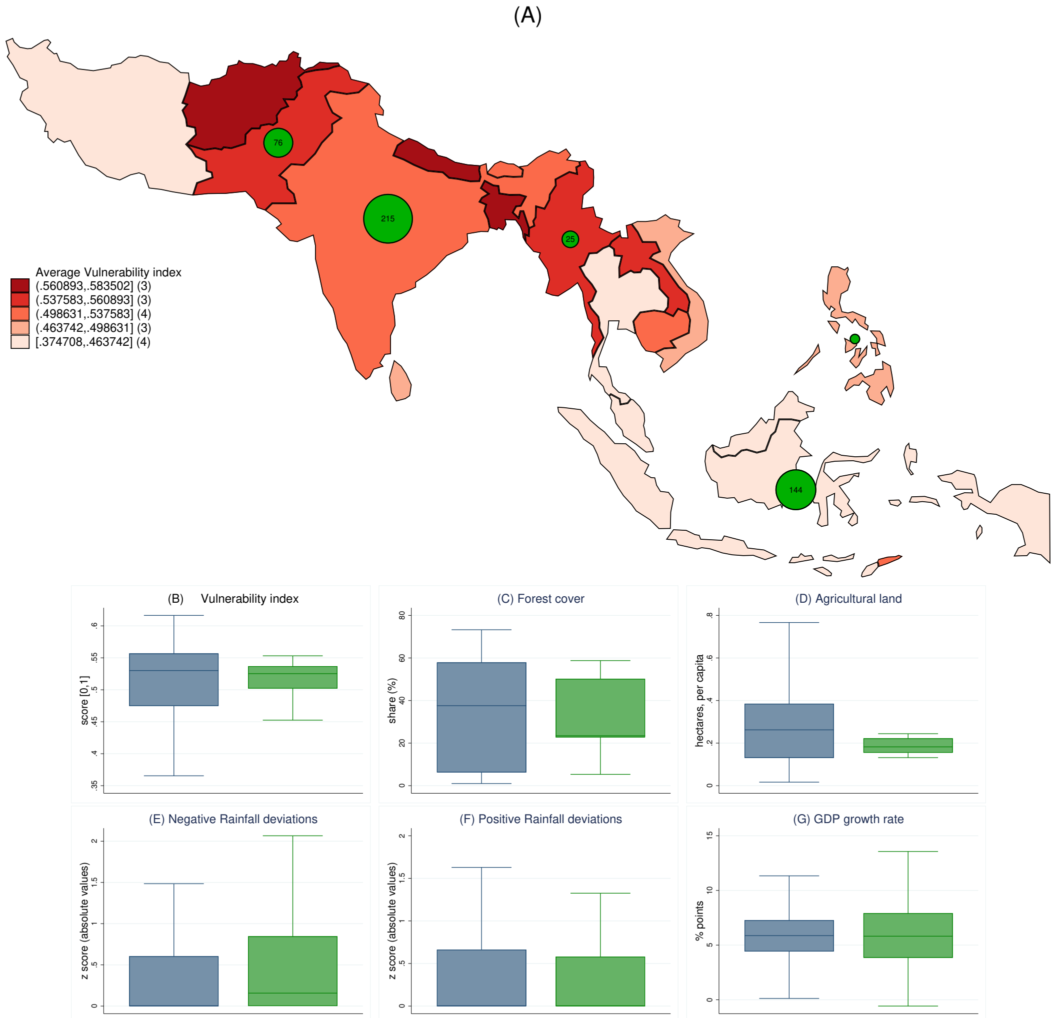

Figure 5: **Vulnerability index and incidence of events of communal violence in South/South-East Asia.** Panel **(A)** illustrates average vulnerability country levels over the period 1995-2016 and the occurrence of events of communal violence. Darkest shades refer to higher vulnerability and green circles are proportional to the absolute number of events. Box-plots show median, 1st and 3rd quantiles of **(B)** vulnerability index, **(C)** forest share, **(D)** agricultural land *per capita*, **(E)** and **(F)** rainfall deviations, and **(G)** GDP growth rate for respectively countries not characterized by communal conflicts (blue) and experiencing communal violence (green). The two groups are significantly different in **(D)** at prob |z| <0.001.

At a glance, rainfall anomalies and GDP growth rate do not seem to depict different scenarios between country/year peaceful observations and those characterized by communal violence.

Once we arrived at the empirical analysis, however, a more nuanced evidence emerges: we found strong evidence that vulnerability to climate hazards - understood in a broad sense involving interdependent socio-economic and geographical components - predicts the risk of communal violence in SSA, whereas no significant relation is shown in S-SEA (Table 1). Looking at SSA, we are not able to distinguish the underlying mechanism inducing the effect among the multiple connections proposed by the empirical literature (see Section 1). Given the methodological approach applied in this study, however, exploring such distinction would still remain fruitless due to the multifaceted inner structure of the concept of vulnerability (O'Brien et al. 2007). It is worth underlining, instead, that vulnerability to climate change does not induce the same social instability across the regions, but is most likely due to prevailing social and economic structures.

Table 1: Likelihood of events of communal violence (1995-2016)

	Sub-Saharan Africa				South/South-East Asia			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
vulnerability$_{(t-1)}$	1.280**	1.275**	1.475**	1.455**	1.498	1.473	0.535	0.424
	(0.534)	(0.517)	(0.675)	(0.675)	(1.692)	(1.833)	(0.793)	(0.693)
forest share	-0.029**	-0.030**	-0.037*	-0.037*	-0.002	-0.004	-0.013	-0.019
	(0.015)	(0.015)	(0.020)	(0.019)	(0.017)	(0.018)	(0.020)	(0.022)
agric pc$_{(t-1)}$	-0.307***	-0.330***	-0.419**	-0.426**	-5.153*	-4.308*	-6.930**	-5.643**
	(0.107)	(0.121)	(0.212)	(0.209)	(3.063)	(2.495)	(2.796)	(2.261)
neg rainfall dev	-0.078		-0.116		0.431***		0.744***	
	(0.155)		(0.175)		(0.155)		(0.282)	
pos rainfall dev		-0.038		0.050		-0.183***		-0.552***
		(0.171)		(0.223)		(0.060)		(0.132)
GDP growth$_{(t-1)}$	-0.064***	-0.064***	-0.064***	-0.063***	-0.003	-0.008	-0.000	0.000
	(0.018)	(0.018)	(0.021)	(0.021)	(0.038)	(0.039)	(0.037)	(0.041)
communal violence$_{(t-1)}$	0.979***	0.976***	1.050***	1.071***	0.883***	0.821**	1.278***	1.212***
	(0.331)	(0.309)	(0.324)	(0.304)	(0.327)	(0.357)	(0.240)	(0.281)
constant	-20.080***	-19.593***	-20.972***	-21.068***	-9.188	-8.881	-5.479	-4.020
	(6.249)	(6.043)	(7.719)	(7.505)	(9.554)	(10.273)	(3.868)	(3.410)
Sub-regional fixed effects:								
Western Africa	11.392***	10.971***	11.919**	12.108***				
	(3.961)	(3.871)	(4.751)	(4.519)				
Eastern Africa	11.506***	11.093***	12.050***	12.241***				
	(3.702)	(3.644)	(4.598)	(4.417)				
Middle Africa	12.530***	12.141***	13.333***	13.513***				
	(3.939)	(3.861)	(4.945)	(4.752)				
South Asia					-1.067	-1.090	-1.043	-1.110
					(1.278)	(1.283)	(1.335)	(1.241)
Time fixed effects	No	No	Yes	Yes	No	No	Yes	Yes
Obs	935	935	935	935	366	366	330	330
AIC	329	329	353	354	154	157	147	151
BIC	382	382	503	504	189	192	211	220

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Note: Panel probit regression coefficients with standard errors clustered at country level in parentheses. Sub-regional fixed effects apply to all models. Time fixed effects apply to models (3) and (4) for Sub-Saharan Africa, and models (7) and (8) for South/South-East Asia.

In this regard, it is worth noting that even small differences in climate hazards can be reflected into sizeable impacts when countries are markedly vulnerable (Chen et al. 2015). We, therefore, calculated the predicted probabilities of the outbreak of communal conflicts events, given different current scores of vulnerability to climate change. Results are plotted in Figure 6. According to the outcomes of our analysis, in SSA a minimum vulnerability score of 0.48 is associated to a statistically significant increase in the likelihood of communal violence. We can remark that in all African sub-regions the average vulnerability score is higher than that level, with threatening situations such as in Chad and Niger (where vulnerability scores are respectively 0.63 and 0.68, on average). Not surprisingly, both countries experienced communal violence. Above all, the results clearly signal the increasing insecurity associated with a possible rise in the vulnerability score in terms of communal violence.

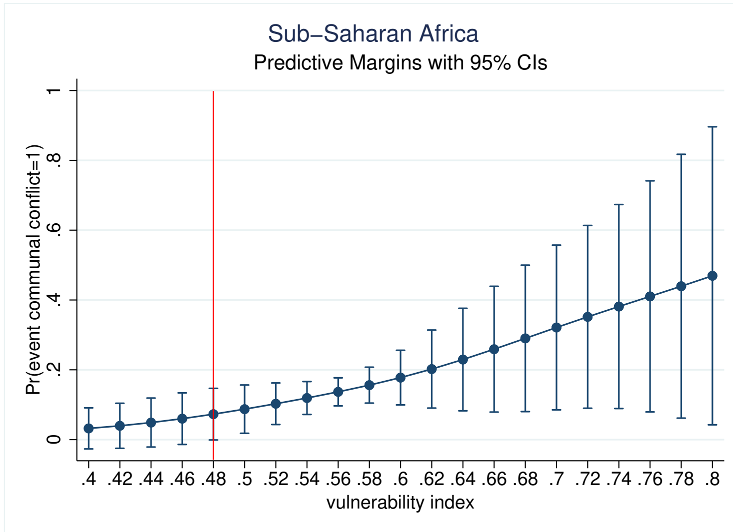

Figure 6: **Predicted probabilities of communal violence outbreak.** The chart provides predictive margins for communal violence occurrence at different current scores of vulnerability. The vertical red line indicates the lowest score achieving statistical significance.

Forest share appears to be another significant correlate of communal conflict in SSA. Larger forested areas reduce the risk of communal violence, most likely by providing shelter and livelihood essentials to impoverished social groups that usually live there.

One of the most meaningful results is represented by the role of agricultural land *per capita*. We included this covariate as proxy of individual productive means, including both cropland and pasture land. Indirectly, this variable furnishes a measure of the pressure over natural resources - namely land and water - given the population size. In both regions, larger amounts of agricultural land per person are significantly associated with a reduction of communal violence outbreak. Again, having access to productive inputs and enjoying economic opportunities appear decisive conditions. This effect is particularly accentuated in S-SEA.

In contrast to previous studies (see for example, Fjelde & von Uexkull (2012)) our results do not provide support to the idea that climate variability - measured as rainfall anomalies - contributes to the triggering of communal conflicts in SSA, whereas we found strong evidence of their role in S-SEA region. Here, wetter years are associated with a reduction of the likelihood of communal violence. In S-SEA region rain-fed agriculture accounts for 60-65% of agricultural land, including both agro-pastoral systems, characterized by low productivity, and highly-productive rice-based systems that suffer, however, from ever-more fragile ecosystems and reduction in water availability (Dubois et al. 2011). In both scenarios and given overall increasing temperatures, rainfall abundance might facilitate local economic systems of production, increasing economic opportunities, reducing food insecurity and making conflict less likely (Wischnath & Buhaug 2014).

Across all models, we found strong evidence that communal violence shows high temporal recurrence; in fact, having experienced events of communal conflict in the past markedly increases the probability of new occurrences. This result confirms well-established evidence in the civil conflict literature. Nevertheless, it is worth noting that our focus on communal violence refers to the occurrence of less organized conflicts, and thus the result suggests that violence breeds violence also at a very low level of organization. Furthermore, the persistence of communal violence shows also a spatial dimension; the number of affected countries remain quite limited and consistent throughout the period considered. According to our findings, the heterogeneity of socio-environmental characteristics matters in Sub-Saharan Africa, where sub-regional fixed effects are steadily and highly significant. This does not apply to S-SEA where a higher sub-regional homogeneity sheds light on country-level determinants of communal violence.

Overall, results uncover a geographical pathway which supports generalizing the results obtained on a single world region (what we called "one-fits-all" approach) as an approach that could arrive to misleading considerations and, eventually, to the adoption of unfocused policy options. Returning to the findings of this study, while reducing overall vulnerability to climate change represents a sound policy for increasing social stability in Sub-Saharan Africa, at least as far as regards the risk of communal violence, the same approach could result less effective in South/South-East Asia. Here, the degree of vulnerability to climate hazards failed to reveal a systematic relationship with communal violence, whereas other factors stand out as determinants. Adaptation measures should target agricultural production capabilities in order to reduce - among other goals - the likelihood of communal violence.

4 Concluding remarks

The climate-conflict literature converges upon a substantial consensus supporting the argument that climate change indirectly supports social instability under specific conditions which make its effects disruptive for human societies. The prevalence of climate-sensitive economic systems dependent on land-related resources (such as rain-fed agriculture) and low levels of development nourish the possibility that climate change incites competition for increasingly scarce resources, determines forced displacement, increases livelihood insecurity by altering agricultural productions. Such effects, although through distinct mechanisms, are likely to increase the risk of conflict.

It is within this perspective, therefore, that it is important to what extent countries are overall susceptible to the effects of a changing climate. We argue that country vulnerability to natural hazards - being a complex intertwined connection between exposure, sensitivity and adaptive capacity - is a key determinant for understanding indirect linkages between climate change and the occurrence of violence. Focusing on vulnerability allows us to simultaneously consider multiple dimensions whose relations are characterized by causal intra-linkages and feedback loops. While on one hand this approach does not allow for disentangling the underlying casual mechanisms above-mentioned, it does have the advantage of not falling into forced reductionism where multiple and interconnected mechanisms are likely to be at play.

This research work provides an innovative contribution to the climate-conflict literature by analysing geographically diversified pathways linking vulnerability to climate hazards to the occurrence of events of communal violence in Sub-Saharan Africa and South/South-

East Asia. Two elements are at the basis of the analysis and provide a profile for the relevance of results. First, we concentrated the analysis on communal violence - that is deadly armed events involving non-state actors whose mobilization is based on identity relations such as ethnic or religious ties - since it refers to groups who traditionally base their livelihoods on climate-sensitive economic activities. Second, we shed light on a region - South/South-East Asia - which is rarely explored in the empirical climate-conflict literature, although it results in being characterized by organized violence and highly exposed to the effects of climate change. This methodological choice allows us to test our hypothesis on a broader geographical perspective, sorting out regional-specific pathways of climate change conditional effects on communal violence.

Relying on the ND-GAIN vulnerability index and other socio-economic and climatic features gathered from multiple sources, we first outlined a comprehensive picture of countries' susceptibility to climate change in these regions.
Then, analysing the period 1995-2016, we found strong evidence that greater vulnerability is conducive to a higher risk of communal violence in Sub-Saharan Africa (SSA), whereas in South/South-East Asia (S-SEA) we did not find any correlation pattern. In SSA, a current vulnerability score of 0.46 (in a 0-1 range) is associated with a significant increase in the risk of communal violence. It should be underlined that the majority of African countries largely overcomes such a threshold (average score within the region is 0.5423, over the period 1995-2016) and this empirical evidence points out the relevance of vulnerability to climate change in terms of social stability within this area. On the other hand, S-SEA results suggest that current climate variability (measured as rainfall deviations within the period, statistically significant in all model specifications) exerts a greater effect on communal violence outbreak than overall vulnerability to climate change. In general, greater access to productive means - which is measured by agricultural land *per capita*, including both cropland and pasture land - is conducive to a reduction of risk of communal violence.

Our findings - robust to a series of alternative specifications - can help in informing a number of key policy decisions in different arenas. In particular, we derived some policy implications which calls for an integrated approach between climate policies and social stability efforts: i) climate decision-making requires overcoming a ”one-fits-all” approach, calling for context-based analysis able to prioritise interventions; ii) in Sub-Saharan Africa policy efforts aimed at reducing vulnerability to climate hazards (namely, increasing adaptation), and forest-based mitigation initiatives are powerful tools making societies not only more resilient towards climate change effects, but also more peaceful; iii) in South-South-East Asia adaptation measures should be pursued in the agricultural sector since current climate variability impacts on the risk of communal violence most probably by deteriorating agricultural capacities and livelihood essentials.

Appendix

This document adds descriptive statistics and information for the variables used in the study, in detail:

- Table A1 provides description of variables, including data sources;
- Table A2 provides regional summary statistics;
- Table A3 and Table A4 list all countries included in the analysis by region, specifying the occurrence of communal violence and providing country-specific mean, standard deviation and overall variation across the period of the vulnerability index;
- Table A5 describes the indicators used for the calculation of the ND-GAIN vulnerability index;
- Table A6 illustrates the results of some robustness checks, as described in Section 2.

Table A1: Variables description

Variable	**Description**	**Data Source**
comm conf	Occurrence of at least one event of communal violence (binary: 0,1)	UCDP-GED
vulnerability	Vulnerability index to climate hazards (range: 0-1)	ND-GAIN
forest share	Share of national territory covered by forests (%)	WDI and FAOSTAT
agric pc	*Per capita* agricultural land (hectares *per capita*)	WDI and FAOSTAT
neg rainfall dev	Negative deviation of total yearly precipitations from average precipitation level over the period (z scores, absolute values)	CCKP-World Bank
pos rainfall dev	Positive deviation of total yearly precipitations from average precipitation level over the period (z scores, absolute values)	CCKP-World Bank
GDP growth	GDP growth rate (%)	WDI

Table A2: Summary statistics, by region

	Sub-Saharan Africa					South/South-East Asia				
	Obs.	Mean	Std.Dev	Min.	Max.	Obs.	Mean	Std.Dev.	Min.	Max.
comm conf	1012	.1679	.3740	0	1	396	.0959	.2949	0	1
vulnerability	1012	.5423	.0589	.4081	.7043	396	.5109	.0597	.365	.6163
forest share	1012	23.94	19.57	.324	73.11	396	33.79	23.11	1	73.24
agric pc	1012	2.328	2.896	.0163	23.847	396	.3536	.3675	.0166	2.084
neg rainfall dev	1012	.3986	.5820	0	3.043	396	.3781	.5806	0	3.368
pos rainfall dev	1012	.3928	.5866	0	3.624	396	.3682	.5683	0	2.754
GDP growth	979	4.768	7.511	-36.3	149.9	381	5.730	3.855	-13.1	26.11

The empirical analysis includes controls for continental sub-regions, which are defined according to the United Nations Geoscheme, as follows:

- *Western Africa*: Guinea-Bissau; The Gambia; Mali; Senegal; Benin; Mauritania; Niger; Ivory Coast; Guinea; Burkina Faso; Liberia; Sierra Leone; Ghana; Togo; Nigeria.
- *Eastern Africa*: Uganda; Kenya; ; Tanzania; Burundi; Rwanda; Somalia; Ethiopia; Eritrea; Mozambique; Zambia; Zimbabwe; Malawi; Madagascar; Sudan.
- *Middle Africa*: Equatorial Guinea; Cameroon; Gabon; Central African Republic; Chad; Republic of the Congo; Democratic Republic of the Congo; Angola.
- *Southern Africa*: South Africa; Namibia; Lesotho; Botswana; Swaziland.
- *Southern Asia*: Iran; Afghanistan; India; Bhutan; Pakistan; Bangladesh; Sri Lanka; Nepal.
- *South-Eastern Asia*: Myanmar; Thailand; Cambodia; Lao; Vietnam; Malaysia; Philippines; Indonesia; Timor-Leste.

Table A3: List of sub-Saharan Africa (SSA) countries and descriptive statistics

Sub-Saharan Africa, 1995-2016					
Country	Communal Violence	Number of events	Vulnerability Index		
			Mean	St.Dev.	Overall Δ
Angola	no		0.5177	0.0096	-0.0261
Benin	no		0.5834	0.0054	-0.0180
Botswana	no		0.4824	0.0075	-0.0300
Burkina Faso	no		0.5819	0.0114	-0.0320
Burundi	no		0.5643	0.0058	0.0044
Cameroon	yes	2	0.4829	0.0029	-0.0082
Cape Verde	no		0.4527	0.0123	-0.0030
CAR	yes	100	0.5517	0.0123	0.0272
Chad	yes	17	0.6282	0.0085	-0.0163
Comoros	no		0.5527	0.0173	-0.0417
Dem. Rep. Congo	yes	114	0.5919	0.0115	0.0249
Equat. Guinea	no		0.4780	0.0132	-0.0141
Eritrea	no		0.5912	0.0060	0.0006
Ethiopia	yes	213	0.5785	0.0083	-0.0229
Gabon	no		0.4328	0.0060	-0.0214
Ghana	yes	24	0.4929	0.0173	-0.0348
Guinea	yes	5	0.5320	0.0087	-0.0069
Guinea-Bissau	no		0.6303	0.0088	0.0116
Ivory Coast	yes	40	0.5116	0.0056	0.0029
Kenya	yes	409	0.5388	0.0062	-0.0052
Lesotho	no		0.4584	0.0114	0.0171
Liberia	no		0.6009	0.0104	0.0244
Madagascar	no		0.5555	0.0088	0.0165
Malawi	no		0.5650	0.0105	-0.0222
Mali	yes	10	0.6068	0.0065	-0.0149
Mauritania	no		0.5496	0.0080	-0.0033
Mauritius	no		0.4496	0.0029	-0.0054
Mozambique	no		0.5299	0.0093	-0.0294
Namibia	no		0.4873	0.0078	-0.0163
Niger	yes	3	0.6831	0.0144	-0.0333
Nigeria	yes	678	0.5135	0.0109	-0.0231
Rep. of Congo	no		0.5214	0.0092	-0.0332
Rwanda	no		0.5615	0.0127	-0.0014
Senegal	no		0.5529	0.0125	-0.0286
Seychelles	no		0.4932	0.0052	-0.0159
Sierra Leone	no		0.5673	0.0076	-0.0120
Somalia	yes	180	0.6802	0.0026	-0.0051
South Africa	no		0.4173	0.0065	-0.0231
Sudan	yes	286	0.6147	0.0058	-0.0111
Swaziland/eSwatini	no		0.5176	0.0124	0.0225
Tanzania	no		0.5459	0.0072	0.0038
The Gambia	no		0.5316	0.0153	0.0455
Togo	no		0.5163	0.0080	-0.0047
Uganda	yes	90	0.5850	0.0071	0.0125
Zambia	no		0.5370	0.0054	-0.0008
Zimbabwe	no		0.5279	0.0097	0.0264

Note: Bold names indicate countries where communal violence occurred.

Table A4: List of S-SEA countries and descriptive statistics

Southern/South-Eastern Asia, 1995-2016					
Country	Communal Violence	Number of events	Vulnerability Index		
			Mean	St.Dev.	Overall Δ
Afghanistan	no		0.5835	0.0067	0.0031
Bangladesh	no		0.5693	0.0123	-0.0363
Buthan	no		0.5270	0.0152	-0.0407
Cambodia	no		0.5375	0.0178	-0.0502
India	yes	216	0.5209	0.0113	-0.0302
Indonesia	yes	144	0.4637	0.0102	-0.0239
Iran	no		0.4055	0.0077	-0.0106
Laos	no		0.5608	0.0175	-0.0231
Malaysia	no		0.3747	0.0055	-0.0109
Myanmar	yes	25	0.5477	0.0076	0.0020
Nepal	no		0.5609	0.0216	-0.0528
Pakistan	yes	76	0.5399	0.0064	-0.0213
Philippines	yes	8	0.4885	0.0108	-0.0273
Sri Lanka	no		0.4775	0.0060	-0.0002
Thailand	no		0.4346	0.0074	-0.0178
Timor-Leste	no		0.5300	0.0110	-0.0176
Vietnam	no		0.4986	0.0121	-0.0374

Notes: Bold names indicate countries where communal violence occurred.

Table A5: Internal structure of the ND-GAIN Vulnerability Index, by sector and components

	ND-GAIN Vulnerability Index		
Sector	Components		
	Exposure	*Sensitivity*	*Adaptive capacity*
Food	Projected change of cereal yields	Food import dependency	Fertilizer,irrigation pesticide and tractor use
	Projected population change	Rural population	Child malnutrition
Water	Projected change of annual runoff	Fresh water withdrawal rate	Access to reliable drinking water
	Projected change of annual groundwater recharge	Water dependency ratio	Dam capacity
Health	Projected change of deaths from climate induced diseases	Slum population	Medical staff
	Projected change of length of transmission season of vector-borne diseases	Dependency on external resource for health services	Access to improved sanitation facilities
Ecosystem services	Projected change of biome distribution	Dependency on natural capital	Protected biomes
	Projected change of marine biodiversity	Ecological footprint	Engagement in intern. environm. conventions
Human habitat	Projected change of warm period	Urban concentration	Quality of trade transport related infrastructure
	Projected change of flood hazard	Age dependency ratio	Paved roads
Infrastructure	Projected change of hydropower generation capacity	Dependency on imported energy	Electricity access
	Projection of sea level rise impacts	Population living under 5 m above the sea	Disaster preparedness

Notes: The component *Exposure* is calculated as projected changes of individual indicators to mid-century expected values. For example, projected change of annual runoff (defined as precipitation minus evapotranspiration and change in soil moisture storage) corresponds to the percent change between the baseline projection (1980-2009) and the future projection (2040-2069). Original data source: Aqueduct, World Resource Institute. All other indicators are yearly measured.

Table A6: Robustness checks. Likelihood of events of communal violence (1995-2016)

	Sub-Saharan Africa				South/South-East Asia			
	Probit		Panel Probit		Probit		Panel Probit	
	(R1)	(R2)	(R3)	(R4)	(R5)	(R6)	(R7)	(R8)
vulnerability$_{(t-1)}$	0.323**	0.320**	1.543***	1.549***	0.001	0.010	1.231	1.194
	(0.147)	(0.146)	(0.413)	(0.408)	(0.158)	(0.151)	(1.473)	(1.538)
forest share	-0.012***	-0.011***	-0.016	-0.017	0.002	0.003	0.006	0.005
	(0.003)	(0.003)	(0.013)	(0.013)	(0.006)	(0.006)	(0.017)	(0.017)
agric pc$_{(t-1)}$	-0.076**	-0.079**	-0.262***	-0.285***	-1.677***	-1.574***	-4.296**	-3.659**
	(0.032)	(0.033)	(0.088)	(0.104)	(0.469)	(0.422)	(2.072)	(1.730)
neg rainf dev	-0.173		-0.092		0.288*		0.426***	
	(0.109)		(0.155)		(0.174)		(0.150)	
pos rainf dev		-0.011		0.083		-0.186***		
		(0.126)		(0.198)		(0.053)		
GDP growth$_{(t-1)}$	-0.017**	-0.017*	-0.065***	-0.065***	0.014	0.011	-0.002	-0.007
	(0.009)	(0.009)	(0.018)	(0.018)	(0.024)	(0.024)	(0.037)	(0.038)
communal violence$_{(t-1)}$	2.180***	2.163***	0.974***	0.970***	1.704***	1.721***	0.901***	0.843**
	(0.148)	(0.147)	(0.325)	(0.306)	(0.239)	(0.239)	(0.322)	(0.342)
constant	-6.937***	-6.924***	-10.645***	-10.735***	-1.187	-1.240	-8.598	-8.241
	(0.867)	(0.868)	(2.560)	(2.642)	(1.123)	(1.086)	(8.626)	(9.008)
Sub-regional fixed effects:								
Western Africa	4.104***	4.086***	No	No				
	(0.173)	(0.170)						
Eastern Africa	4.259***	4.245***	No	No				
	(0.152)	(0.149)						
Middle Africa	4.434***	4.418***	No	No				
	(0.175)	(0.170)						
Southern Asia					0.026	0.010	No	No
					(0.249)	(0.251)		
Time polynomials	Yes	Yes	No	No	Yes	Yes	No	No
Obs	935	935	935	935	366	366	366	366
AIC	453	455	328	328	186	188	153	156
BIC	516	518	367	367	229	231	184	187

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Models (R1-R2) and (R5-R6) are estimated by probit link function with time polynomials and regional fixed effects. Models (R3-R4) and (R7-R8) reports panel probit regression coefficients without fixed effects. All models show standard errors clustered at country level in parentheses.

To verify the soundness of results, we performed some robustness checks, whose outcomes are reported in Table A6. First, we changed the estimation technique and re-estimated the models applying a probit link function and modelling the time trend through the inclusion of time polynomials. Second, we relaxed the imposition of sub-regional and time fixed effects, keeping the original estimation approach. With the exception of forest share in SSA which appears associated to the sub-regional connotation, in both robustness checks coefficients' sign and significance levels are confirmed, underlining the validity of the vulnerability-communal conflict pattern previously described. Different regional pathways are also confirmed to be at play.

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