UNIVERSITÀ CATTOLICA del Sacro Cuore

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Sara Balestri, Department of International Economics, Institutions and Development, Università Cattolica del Sacro Cuore, Milano, Italy

✉ sara.balestri@unicatt.it

Raul Caruso, Department of Economic Policy & Centre of Applied Economics (CSEA), Università Cattolica del Sacro Cuore, Milano, Italy – Catholic University 'Our Lady of Good Counsel', Tirana, Albania, European Center of Peace Science, Integration and Cooperation (CESPIC)

✉ raul.caruso@unicatt.it

Dipartimento di Politica Economica
Università Cattolica del Sacro Cuore – Largo A. Gemelli 1 – 20123 Milano
Tel. 02-7234.2921

✉ dip.politicaeconomica@unicatt.it

https://dipartimenti.unicatt.it/politica_economica

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Abstract

This paper examines the influence of climate change vulnerability on the likelihood and severity of communal violence, with a particular emphasis on delineating large-scale regional patterns. Specifically, the analysis centres on Sub-Saharan Africa and South/South-East Asia - both regions being predominantly characterized by rain-fed agriculture and climate-sensitive economic activities - spanning the years 1995 to 2021. Relying on the ND-GAIN Vulnerability Index as a multidimensional measure for propensity of societies to be negatively impacted by climate change, we found robust evidence that greater vulnerability is conducive to a higher likelihood and severity 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 significantly associated to the reduction of communal violence.

JEL classification: D74, O13, Q54, Q56

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

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[1]Correspondence Address: Sara Balestri, Universitá Cattolica del Sacro Cuore, Largo Gemelli 1, 20123 Milan, Italy. Email:sara.balestri@unicatt.it ORCID: 0000-0002-4070-4665

1 Introduction

This paper enriches the climate-change literature by exploring whether vulnerability to climate change affects the likelihood and severity of communal violence, with a particular emphasis on delineating large-scale regional patterns. The attention paid to vulnerability is particularly relevant as it has been recognized (along with other non-climate factors) as a primary factor shaping short-term peace risk (O'Neill et al., 2022). Furthermore, vulnerability is deeply connected to the choices and actions of social actors, therefore it can be modified through targeted interventions.

The rationale behind the analysis is that climate-related impacts greatly vary according to the level of exposure and vulnerability of territories (Lee et al., 2023). Vulnerability to climate change is a multidimensional and dynamic phenomenon whose measurement requires a comprehensive approach. To capture it, we employed the quantitative measure elaborated by 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). This index has been broadly used to inspect challenges and adaptive opportunities associated with climate uncertainty in different domains, such as the effects on agricultural yields (Epule, Ford & Lwasa, 2017), adaptation investment decision-making (Chen, Hellmann, Berrang-Ford, Noble & Regan, 2018), sovereign borrowing (Beirne, Renzhi & Volz, 2021), and firms' cost of capital and access to finance (Kling, Volz, Murinde & Ayas, 2021). Yet, the use of the ND-GAIN Vulnerability Index in the study of armed conflicts is still limited with the noticeable exception of Buhaug and von Uexkull, 2021 which provides a detailed global descriptive analysis of the interconnection between vulnerability, conflict and climate-related impacts.

Our paper differs from the existing literature since it provides a multi-regional empirical analysis linking vulnerability to climate change to a specific form of violence (namely, communal violence) whose perpetrators often depend on climate-sensitive livelihoods, rain-fed agriculture and pastoralism. Indeed, climate change concerns envisage the in-depth destabilization of traditional livelihoods and the increasing inaccessibility of natural resources. For this reason, we moved towards examining organized violence involving those groups particularly vulnerable to such effects, namely communal groups. This term refers to entities primarily bound by religious, ethnic, or linguistic affiliations, often engaged in traditional economic activities like subsistence agriculture and pastoralism.

We empirically test this correlation over the period 1995-2021 within a homogeneous subset of communal violence events, proposing plausible underlying patterns. The methodological choice of focusing on communal violence results consistent with that climate-conflict literature addressing the climate-induced competition over renewable (scarce) resources (among others, see Nordkvelle, Rustad and Salmivalli, 2017; van Weezel, 2019. Furthermore, we also shed light on potential regional nuances. Specifically, we conducted separate analyses for Sub-Saharan Africa (hereafter referred to as SSA) and South/South-East Asia (hereafter referred to as S-SEA), the latter being relatively under-explored in terms of climate change effects on conflict events. (Wischnath & Buhaug, 2014).

Empirically, we estimated both likelihood and severity of communal violence, incorporating the vulnerability index alongside a concise set of control variables. Our findings reveal a distinct large-scale regional pattern, wherein vulnerability to climate change amplifies both dimensions of communal violence in Sub-Saharan Africa. Conversely, in South/South-East Asia, vulnerability does not exhibit a significant association with communal violence, with climate variability still emerging as a determinant. Among other controls, the unavailability of agricultural land for rural populations shows up being a strong predictor of communal violence in both regions.

In addition, the analysis has been enriched by multiple additional estimations and underwent rigorous robustness checks, confirming our findings.

The remainder of this paper is organized as follows. Section 2 provides an overview of the related literature. Section 3 depicts the methodology and Section 4 describes the data used in the empirical analysis. Section 5.1 presents the results, including the salient features of additional estimations and robustness checks. Finally, Section 6 offers concluding remarks.

2 *Related literature*

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 direct causal climate effect over conflict risk is indeed far from being established (see, for example, Mach et al., 2019; Von Uexkull and Buhaug, 2021). The study of the effects of rainfall anomalies exemplifies this inconsistency. While some studies have found that abundant precipitations increase violent events in diverse contexts (Raleigh & Kniveton, 2012; Witsenburg & Adano, 2009), O'Loughlin et al., 2012 shows that periods characterized by abundant rainfall are more peaceful, and according to Fjelde and von Uexkull, 2012 droughts increase the likelihood of violent events, providing support to the environmental scarcity argument.

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), geographical areas, in addition to diversified methodological approaches and scale of analysis (Cappelli et al., 2020).

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 (Creti, Delacote & Leblois, 2021) and socio-economic structures hindering local development (Caruso, Petrarca & Ricciuti, 2016), stimulating human displacement and migration (Maurel & Tuccio, 2016; Withagen, 2014) and increasing the probability of inter-group conflicts (Hegre et al., 2016; Hodler & Raschky, 2014). Within this scenario, weak institutional settings 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 into this branch of literature and further enriches the debate by broadening the perspective of the analysis and focusing on the role of vulnerability to climate change. In fact, the magnitude of climate change impacts largely depends on the degree of vulnerability of a territory 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 (Field et al., 2014). According to the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) the concept of vulnerability encompasses a variety of elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt to the effects of climate change (Lee et al., 2023).

We argue that a higher degree of vulnerability makes livelihood essentials more precarious and their preservation intensely challenged by the effects of climate change. Additionally, the distress caused by climate conditions on production systems is likely to foster the risk of inter-group violence, by inducing scarcity and exacerbating competition over land and water resources. Therefore, to understand the conditional effects of climate change on the outbreak of violence, it results useful exploring the impact of vulnerability on that kind of violence perpetuated by those groups depending on traditional livelihoods (e.g., smallholder farmers, pastor-

alists, fishing communities). In particular, we refer to communal violence.
Communal groups are not permanently organized for combat, and organize themselves along shared common identity lines (such as ethnic ties) to engage in fighting. Communal violence is likely to erupt when resource use patterns change, economic systems are based on the same livelihood requirements and access over scarce resources and local power is problematic(Homer-Dixon, 1999), especially in the case of socioeconomic marginalization (Hillesund, 2019).

Supply-induced scarcity triggers competition over renewable resources, such as grazing land and water, fuelling looting and 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. Frequent example of communal violence include pastoralist violence (Detges, 2014) and cattle theft raids (Döring, 2020) as well as clashes between ethnic communities (Scheffran, Ide & Schilling, 2017).

3 Methods and estimation strategy

We explore the relationship between vulnerability to climate change and events of communal conflict in Sub-Saharan Africa and South/South-East Asia during the period 1995-2021. The decision for centring the geographical scope in such regions is based on the empirical evidence that they share common traits in many meaningful dimensions for the purpose of this study, although they show distinct socio-economic characteristics. On one hand, in fact, both SSA and S-SEA are subject to communal violence and they are classified particularly vulnerable to climate change (Schleussner et al., 2018). In fact, on the basis of the 1.5°C warming limit established in the Paris Agreement, Schleussner et al. (2018) identify key vulnerable regions by overlapping climate hotspots with the Multidimensional Poverty Index (MPI) and inequality data, and indicate SSA and S-SEA among those identified. Moreover, both regions are characterized by widespread rural poverty, dependence on rain-fed agriculture, and a history of violence. We argue that these characteristics outline broad similarities which allow for analysing the determinants of communal violence across these large-scale regions. On the other hand, the existence of large variations in both vulnerability levels - whose source may be embedded in context-specific features - and socioeconomic structures within each region, help us uncovering distinct factors explaining communal violence outbreak.

Further, as Hendrix (2017) points out, scholarly attention in the climate change literature has been greatly devoted to analyse the African context. This operational choice makes sense since 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 and total number 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 the incidence of communal violence and vulnerability scores, is provided in Table A4 and A5 of the Appendix.

Our research hypothesis is that a higher degree of vulnerability to climate change exacerbates the precariousness of traditional livelihoods, whose insecurity reduces the opportunity-cost of mobilizing groups in order to secure their preservation, thus increasing the likelihood of communal violence.

The paper is structured on subsequent stages of analysis. First, we explored through a descriptive analysis the correlation pattern between the incidence of communal violence and vulnerability to climate change across the two selected regions.

As a second step, we developed a statistical model for the likelihood of communal violence (Eq.1), estimated by a random-effect probit model as a function of vulnerability, rainfall anomalies (climate variability), socioeconomic factors (forest share, agricultural land over rural population size and GDP growth) and previous occurrence of communal violence, for every observation in country *i* at year *t*:

$$P(confl = 1|X_{i,t}) = \alpha + \beta_1 Vulner_{i,t} + \beta_2 RainfDev_{i,t} + \beta_3 SocioEcon_{i,t,t-1} + \beta_4 PastConfl_{i,t-1} + \varepsilon_{i,t} \tag{1}$$

To control for unobserved heterogeneity across countries within continuous areas and the potential transboundary nature of climate change stressors, we subsequently included sub-regional fixed effects - defined according to the United Nations Geo-scheme (see Section B2 in the Supplementary Materials). A last model specification includes also time fixed effects. Given the number of available observations and computational limitations, time effects are based on three-year dummy variables. Standard errors are clustered at country level in all model specifications.

Third, we explored whether the same explanatory variables are also determinants of communal conflict violence, measured as the yearly total number of communal conflict events recorded in each country. Our argument is the following: since we expect that vulnerability to climate change is a driver of communal violence outbreak, the persistence of such fragility acts as a conducive element to a higher number of deadly events. Thus, we analysed the severity of communal violence employing a negative binomial estimation. We included the same explanatory variables and controls used in the previous stage of analysis (Eq. 2).

$$severity_{i,t} = \alpha + \beta_1 Vulner_{i,t} + \beta_2 Rainf.Dev._{i,t} + \beta_3 SocioEcon_{i,t,t-1} + \beta_4 PastConfl_{i,t-1} + \varepsilon_{i,t} \tag{2}$$

Eventually, we enriched the analysis through additional estimations and tested the main outcomes against a set of robustness checks, including alternative estimation techniques and sample reductions (see Section B3 and B4 in the Supplementary Materials).

4 Data description

4.1 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) (Croicu & Sundberg, 2015; Sundberg & Melander, 2013) and the Non-State Conflict Dataset to identify all events recognizable as expression of communal violence (Sundberg, Eck & Kreutz, 2012). In the UCDP-GED, all events that result in at least one fatality - within conflicts having at least 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 actors-dyads belonging to non-state conflicts and corresponding to the definition of communal groups; then, we selected all violent events associated to these dyads. For the period of analysis, UCDP-GED reports 3572 events of communal violence in SSA, whereas 534 events took place in S-SEA. 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 communal violence events, S-SEA is undoubtedly less prone to this kind of instability (Figure 1). Conflicts between the Turkana and Pokot pastoralists 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 SSA the most studied area in terms of communal violence (see, for example, Eck (2014), Fjelde and Østby (2014) and van Weezel (2019)).

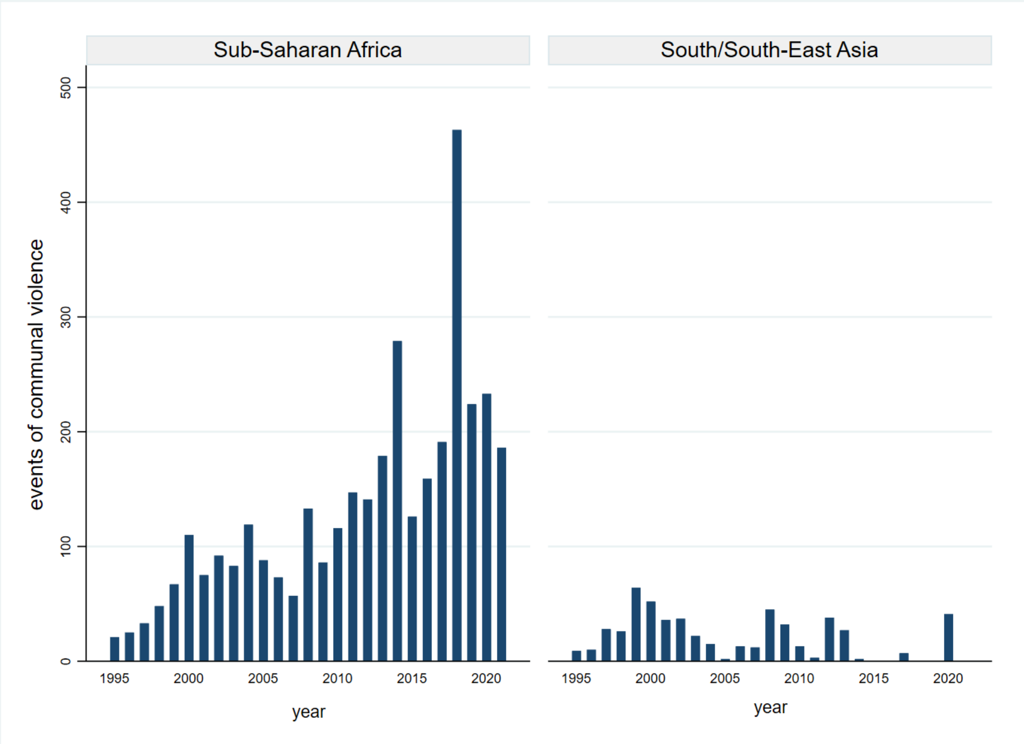

Figure 1: **Occurrence of events of communal violence.** Yearly number of events of communal violence reported in Sub-Saharan Africa and South/South-East Asia (1995-2021). Country-specific information on communal violence occurrence are provided in Table A4 and Table A5 of the Appendix.

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). In S-SEA, communal groups have clashed over land and land-related resources with similar dynamics to what observed in SSA. Environmental degradation, expropriation of communal land, and unequal access to livelihoods represent just some of the processes creating tension between communities in S-SEA (Wilson, 2017).

The diffusion of the phenomenon within the two regions represents another characterizing pattern. While in SSA it is notable a sub-regional variance with a significantly higher incidence of communal violence in the central band of the sub-continent (i.e. West Africa, Middle Africa and East Africa), Asian sub-regions (i.e. South Asia and South-East Asia) appear more homogeneous (see descriptive insights in Figure 2 and Figure 3).

A further consideration should be provided. Some events of communal violence are markedly identifiable as religious in nature, such as the clashes between Christians and Muslims in Nigeria or between Hindus and Muslims in India. While this connotation involves only the 8% of events in SSA, its prominence in S-SEA is much higher representing almost 52% of events. In this latter case, other levers could facilitate the onset of communal (religious) violence in addition to competition over progressively scarce resources or competitive subsistence systems, that is, the dimensions in which we hypothesize a greater effect of vulnerability. To account for this possibility, we run additional estimations to control for the religious nature of the events (see

Section 5.4).

Lastly, we are aware that a possible limitation of this study is the fact that some events of communal violence may not be lethal and therefore escape the operational definition adopted.

4.2 Explanatory variable: vulnerability to climate change

We operationalized the main dimension of the analysis - namely, vulnerability to climate change - by means of the ND-GAIN composite index. It provides a quantitative assessment of vulnerability measuring a country's exposure, sensitivity and capacity to adapt to the negative effects of climate change. The index ranks countries on the basis of their performance on 36 indicators referring to six distinct life-supporting sectors (i.e. food, water, health, ecosystem services, human habitat and infrastructures). The identification of such sectors is consistent with those identified by the United Nations IPCC (Edmonds, Lovell & Lovell, 2020) and the indicators constitute a broad set of social and geopolitical factors which are likely to shape the vulnerability of a society to the effects of a changing climate. The overall vulnerability index score is the unweighted arithmetic mean of the six sectors scores, with higher values expressing greater vulnerability. Table B1 in the Supplementary Materials illustrates the index structure by providing details about the indicators used to track each component.

On average, vulnerability to climate change is fairly high in both regions. SSA appears particularly susceptible to the effects of climate change, with an overall average score of 0.5356. Higher score values are reached in the Sahel and the central-eastern area, although large variations exist. In S-SEA, the average vulnerability score reaches the 0.4978 level, but in this case, too, we found a large country-specific variance. In particular, southern countries - such as Pakistan and Bangladesh - report higher vulnerability as compared to other Asian countries.

Looking at within-period variations, we noticed a steady reduction of vulnerability in both regions (respectively, -3.8% in SSA and -6.5% in S-SEA, on average). Although this pattern may sound highly encouraging, still some countries experienced deteriorating conditions[2] such as Eritrea and Central African Republic where vulnerability increased the most over the period. In both cases, a deficient agricultural capacity (which reflects a country's ability to acquire and deploy agriculture technology) largely determined the worsening. This observation reminds the critical role played by agrarian systems and food production in making societies more resilient to climate change (Buhaug, Benjaminsen, Sjaastad & Theisen, 2015).

Although all countries in S-SEA reduced their vulnerability score during the period of observation, absolute values stay problematically high in some cases, such as Bangladesh. Here, for example, a very low adaptive capacity, associated with an ever present prevalence of poverty and the geographic location, makes the country particularly exposed to the effects of climate change.

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. For readability of results, the index was re-scaled on a 0-10 range for empirical estimations, preserving predictive margins unaffected.

4.3 Control variables

We employ a parsimonious set of control variables, mainly drawn from the existing literature.

A first control captures climate variability. Despite mixed results, several studies suggest a causal relation between precipitation variability and communal violence (among others, Detges (2014), Fjelde and von

[2]These countries are Angola, Burundi, Central African Republic, Chad, Eritrea and Liberia.

Uexkull (2012), Raleigh and Kniveton (2012), van Weezel (2019) and Witsenburg and Adano (2009)). 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 overall water availability (including, for example, the water dependency ratio and the freshwater withdrawal rate), short-term climate variability is unaccounted for. Thus, we introduced a variable measuring the negative deviation of yearly precipitations as compared to the average total precipitation level over the period for each country, expressed as z-score (in absolute values)[3]. We relied on data from the Climate Research Unit (CRU) - retrieved through the World Bank Climate Change Knowledge Portal - to construct the variable.

To further refine the analysis, we carefully identified a set of control variables measuring those elements coherent to our argument and not embodied in the vulnerability index to avoid multicollinearity[4]. First, we included the share of national territory covered by forests. Globally, 1.6 billion people relies on forests for their livelihoods (FAO & UNEP, 2020) and almost a third of the world's forest area is communally managed (Romero & Saavedra, 2021). Forests represent also a primary source of identity for many indigenous groups. Thus, forest loss can destabilize communal livelihoods and trigger competitive dynamics between those groups depending on them. Further, groups living on the edges of forests may have incentives to make those lands differently productive, thus fuelling additional grievances. According to FAO estimates (2022), 75% of all people outside urban areas lived within 1 km of a forest, and about one-third of global forest loss is due to land-use change (forest fires). Interestingly enough, the role of forests has been analysed concerning warfare modalities in case of organized violence outbreak (for example, Chow and Han, 2023; Rustad, Rød, Larsen and Gleditsch, 2008; Tollefsen and Buhaug, 2015) leading to inconsistent results on their role on a global scale. However, the role of forests as providers of vital goods for communal groups has not been assessed yet. The low level of organization involved in communal violence makes the role of forests important not so much for their impact in warfare, but rather for the role they play in supporting livelihood essentials.

The economic systems of communal groups often rely on farming activities and pastoralism. Access to natural resources is a crucial factor for their livelihoods, to the extent that conflicts between farmers and herders often result in communal violence. Therefore, we used a measure of agricultural land relative to the rural population size of the country - including both cropland and pasture - as a proxy for productive means, to account for potential individual access to essential livelihood resources. Indirectly, this variable also indicates the pressure on natural resources - specifically land and water - given the rural population size of the country. For clarity of interpretation, we operationalized this variable as square kilometres of agricultural land per thousand people living in rural areas. To avoid reverse causality, this measure has been lagged, as population levels are influenced by the outcome of conflicts. Data used to calculate the control variable were obtained from FAOSTAT and World Bank WDI.

In addition to these controls, we also introduced a proxy for economic development, as it could potentially trigger outbreaks of violence. Weak socioeconomic development weakens the economic interdependence between different social groups, leading to increased grievances and reducing the opportunity cost of joining a rebellion. 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 development (Kling et al., 2021). To overcome endogeneity issues, we relied on including the one-year lagged GDP growth rate to account for the overall economic trend regardless the actual economic capacity achieved by a country. Original data are gathered from the World Bank WDI.

[3]We considered negative rainfall deviations only, since goodness-of-fit measures suggest that their inclusion better explain the outcome than positive rainfall anomalies.

[4]Variables correlations are provided in Table A3 of the Appendix.

Finally, since violence begets violence, we added a lagged measure of communal violence incidence (labelled *incidence comm. violence*), measured as the number of past events over the country size.

Data sources and descriptive statistics are summarized in Table A1 and Table A2 of the Appendix.

5 *The empirical analysis*

5.1 A preliminary descriptive analysis

In what follows we first present the connections between communal violence and vulnerability to climate change. In Sub-Saharan Africa, communal violence occurred in countries where vulnerability is relatively higher (panel (A) of Figure 2) and vulnerability scores among country/year observations with at least one event of communal conflict significantly differ from those not subject to communal violence (prob $|z| < 0.000$). Once we look at sub-regional vulnerability levels (panel (B) of Figure 2), the same pattern is found significant in East and Middle Africa where the 58% of events of communal violence of our sample is reported. West Africa, on the other hand, presents a more nuanced reality where Nigeria stands out as the country most affected by communal violence. Although its average vulnerability score over the period (0.5077) may appear not particularly high compared to other African countries, it reaches a critical level in absolute terms.

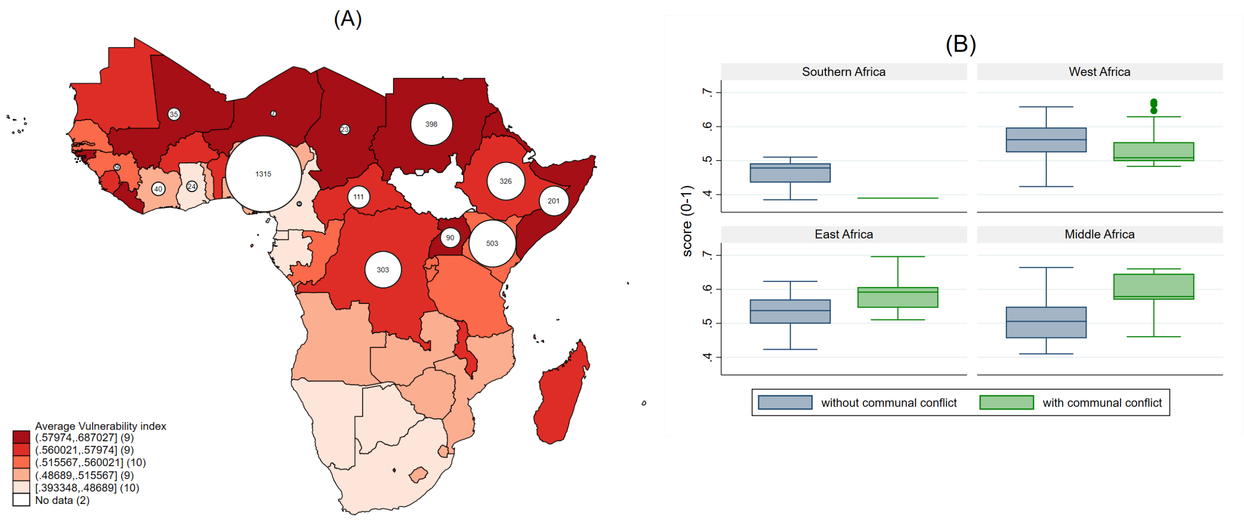

Figure 2: **Vulnerability index and incidence of events of communal violence in Sub-Saharan Africa.** Left-hand panel (A) illustrates average vulnerability country levels over the period 1995-2021 and the occurrence of events of communal violence. Darkest shades refer to greater vulnerability and circles are proportional to the absolute number of reported events. Right-hand panel (B) shows median, 1st and 3rd quantiles of the vulnerability index by SSA sub-regions for respectively countries not characterized by communal conflicts (blue) and experiencing communal violence (green). The two groups are significantly different in East and Middle Africa at prob$|z| < 0.000$.

In South/South-East Asia the correlation pattern appears weaker (panel (A) of Figure 3): no statistically significant differences exist between country/year observations characterized by communal conflict events and those peaceful with respect to this kind of violence. The same holds for sub-regional vulnerability scores (panel (B) of Figure 3). Indonesia provides a plain example: here, a relevant number of deadly events occurred despite a relatively low level of vulnerability (0.4567, on average) which suggests a less straightforward association than what was observed in SSA.

Interestingly, countries characterized by communal violence show a significant lower amount of agricultural land given the rural population size (prob$|z| < 0.001$), suggesting a possible explanatory factor of communal violence incidence in a given country.

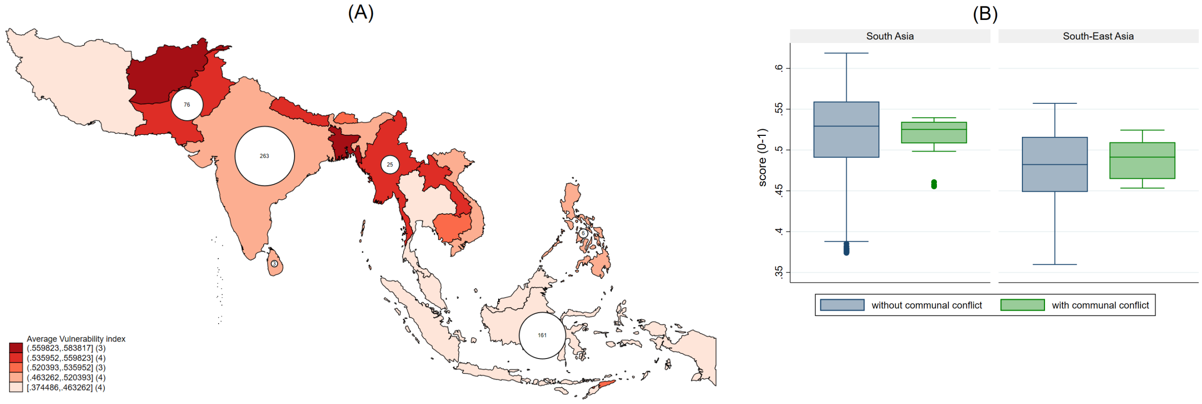

Figure 3: **Vulnerability index and incidence of events of communal violence in South/South-East Asia.** Left-hand panel (A) illustrates average vulnerability country levels over the period 1995-2021 and the occurrence of events of communal violence. Darkest shades refer to greater vulnerability and circles are proportional to the absolute number of reported events. Right-hand panel (B) shows median, 1st and 3rd quantiles of the vulnerability index, by Asian sub-regions for respectively countries not characterized by communal conflicts (blue) and experiencing communal violence (green). The two groups are not statistically different.

5.2 Vulnerability and the likelihood of communal violence

We explored the likelihood of communal violence by means of a probit model with the vulnerability index as main explanatory variable.

The empirical analysis consistently confirms the descriptive insights: we found strong evidence that vulnerability to climate change predicts the outbreak of communal violence in SSA, whereas no significant relation is found in S-SEA (Table 1). Consequently, we argue that vulnerability to climate change fosters a different process of social instability across regions, most likely due to the prevailing social and economic structures.
Sub-regional fixed effects highlight the pervasive role played by vulnerability in the African subcontinent, suggesting a more accentuated role in Middle Africa. The results remain stable once time-fixed effects are applied.

In SSA the higher the vulnerability index, the greater the likelihood of communal violence. 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).
Starting from the lower score reported in Sub-Saharan Africa (namely, 0.38 in South Africa), we calculated the predicted probabilities of outbreak of communal conflicts events applying the model specification including sub-regional fixed effects, and according to increasing scores of vulnerability (Figure 4). It is useful to remark that the average vulnerability score in SSA is 0.5356, with threatening situations, such as Chad, where the index reaches the impressive level of 0.65. Overall, the results clearly signal the risk of growing insecurity (as higher probability of communal violence) when facing increasing levels of vulnerability.

Differently from previous studies on communal violence (see for example, Fjelde and von Uexkull (2012)) our results do not provide support to the idea that climate variability - measured as negative rainfall anomalies - facilitates communal conflicts in SSA, whereas, in line with Bohlken and Sergenti (2010) and Sarsons (2015), we found strong evidence of their role in S-SEA. Here, wetter years are associated with a reduction of communal violence likelihood. In S-SEA region rain-fed agriculture accounts for almost 65% of agricultural land, including both agro-pastoral systems, characterized by low productivity, and highly-productive rice-based sys-

Table 1: Likelihood of events of communal violence (1995-2021)

	Sub-Saharan Africa			South/South-East Asia		
	(1)	(2)	(3)	(4)	(5)	(6)
vulnerability$_{(t-1)}$	1.423***	1.371***	1.489***	1.822	2.040	-0.851
	(0.503)	(0.524)	(0.565)	(2.107)	(2.469)	(0.895)
negative rainfall deviation	-0.182	-0.168	-0.140	0.446***	0.445***	0.552***
	(0.132)	(0.130)	(0.148)	(0.160)	(0.159)	(0.197)
forest share	-0.047***	-0.064***	-0.063***	0.007	-0.006	-0.030
	(0.013)	(0.016)	(0.016)	(0.022)	(0.034)	(0.022)
pc agricultural land$_{(t-1)}$	-0.019***	-0.021**	-0.020**	-0.282***	-0.315**	-0.289**
	(0.007)	(0.008)	(0.009)	(0.108)	(0.145)	(0.125)
GDP growth$_{(t-1)}$	-2.857**	-2.905**	-2.454*	-2.217	-2.312	-5.711
	(1.301)	(1.338)	(1.285)	(3.954)	(3.946)	(4.373)
incidence comm. violence$_{(t-1)}$	0.087***	0.088***	0.093***	0.102***	0.102***	0.091***
	(0.020)	(0.020)	(0.019)	(0.022)	(0.022)	(0.029)
Sub-regional fixed effects	No	Yes	Yes	No	Yes	Yes
Time fixed effects	No	No	Yes	No	No	Yes
Obs	1181	1181	1181	453	453	453
Pseudo-R^2	0.1758	0.1831	0.2092	0.1751	0.1771	0.2873
AIC	397.07	399.68	403.60	175.91	177.53	172.17
BIC	437.66	455.49	500.00	208.84	214.57	242.14

Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Note: Panel probit regression coefficients with standard errors clustered at country level in parentheses.

tems that suffer, however, from evermore fragile ecosystems and reduction in water availability (Dubois, 2011). Given overall increasing temperatures, rainfall abundance might facilitate local economic systems of production (Seo, Mendelsohn & Munasinghe, 2005), increasing economic opportunities, reducing food insecurity and making conflict less likely (Wischnath & Buhaug, 2014).

Forest share ends up being a significant correlate of communal conflict in SSA: larger forested areas reduce the likelihood of communal violence, as hypothesized.

One of the most meaningful results refers to the role played by agricultural land. In both regions, larger amounts of agricultural land per person are significantly associated with a reduction of communal violence probability. This effect is particularly accentuated in S-SEA.

Across all models, communal violence shows high temporal recurrence: in fact, having experienced events of communal violence in the past markedly increases the probability of new occurrences. This result confirms well-established evidence in the civil conflict literature. Nevertheless, since our focus is on communal conflicts - typically smaller in scope and characterized by a lower intensity - it remarks that violence breeds violence also at a very low level of organization.

Overall, results uncover large-scale regional patterns which do not support generalizing the findings obtained by cross-country analyses based on a single geographical area. Such an approach could rather suggest misleading considerations and, eventually, the adoption of unfocused policy options. Returning to the findings of this study, we found evidence that reducing overall vulnerability to climate change would be a sound policy for increasing social stability in Sub-Saharan Africa - at least as far as regards the likelihood of communal violence. However, the same approach could result less effective in South/South-East Asia. Here, the degree of vulnerability to climate change failed to reveal a systematic relationship with communal violence, whereas

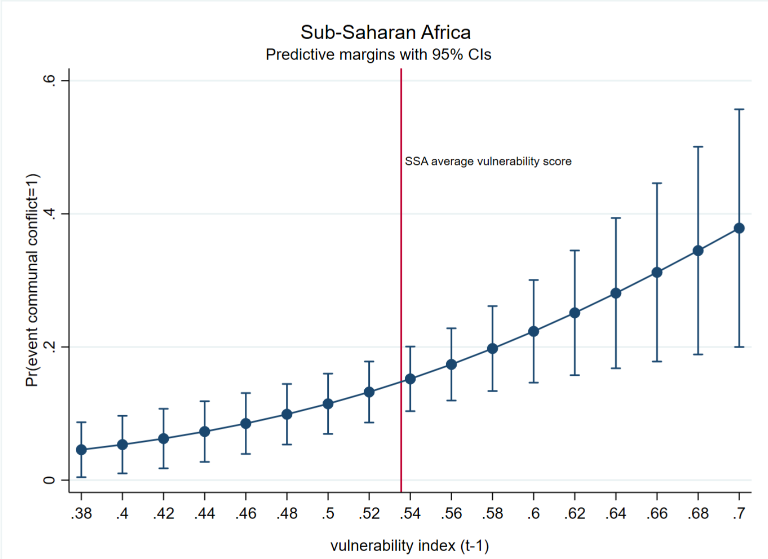

Figure 4: **Predicted probabilities of communal violence outbreak.** The chart provides predictive margins of communal violence outbreak, given increasing levels of the vulnerability index. The vertical line indicates the average vulnerability score in SSA over the period.

other factors stand out as its determinants. For example, adaptation measures should target agricultural production capabilities to reduce the short-term cost of climate variability (Gorst, Dehlavi & Groom, 2018) and the likelihood of communal violence.

5.3 Vulnerability and the severity of communal violence

We continued our analysis by examining the annual count of events occurring in each country. In essence, we aim to investigate whether the factors influencing communal violence incidence can also account for its severity.

As explained in Section 3, we explored this dimension by estimating multiple negative binomial regressions (Table 2). We adopted this estimator since Likelihood Ratio Tests for α=0 strongly reject the null hypothesis that errors do not exhibit overdispersion, and descriptive statistics clearly indicate overdispersion in the dependent variable (see Table A2 of the Appendix), making a Poisson regression unsuitable.

Also in this case, vulnerability to climate change shows up being a determinant in SSA. Put differently, greater levels of vulnerability increase communal conflict likelihood and lead also to a higher cumulative number of violent events, thus providing the conditions for stronger waves of violence to manifest. Our findings corroborate those of Buhaug and von Uexkull, 2021 on civil conflicts. Vulnerability thus plays a role in triggering violence and allowing it to develop over time. Low resilience and fragility to climate hazards can exacerbate local inequality rates and threaten the livelihoods of communal groups, especially in rural areas where access to natural resources and land use may be critical to survival. These factors can facilitate groups mobilization determining a higher number of events of communal violence.

Other findings are consistent with those obtained in the previous stage of analysis, albeit forest share loses much of its relevance in SSA, whereas appears significant in S-SEA with unexpected sign. This last result can be explained by the fact that conflicts over forest resources are widespread in South-East Asia, often occurring between indigenous people and local communities (Yasmi, Kelley & Enters, 2013).

Access to and allocation of productive land is one of the most meaningful predictors of communal violence. In both regions, greater agricultural areas per person, that is greater available productive means in

Table 2: Number of events of communal violence (1995-2021)

	Sub-Saharan Africa			South/South-East Asia		
	(1.1)	(2.1)	(3.1)	(4.1)	(5.1)	(6.1)
vulnerability$_{(t-1)}$	0.706**	0.618*	0.733**	1.571*	1.501	-1.124
	(0.290)	(0.340)	(0.363)	(0.935)	(0.940)	(1.298)
negative rainfall deviation	0.041	0.053	0.088	0.544***	0.547***	0.556**
	(0.116)	(0.115)	(0.124)	(0.208)	(0.209)	(0.251)
forest share	-0.030***	-0.013	-0.004	0.053***	0.061***	0.039
	(0.007)	(0.010)	(0.011)	(0.017)	(0.023)	(0.031)
pc agricultural land$_{(t-1)}$	-0.019***	-0.015**	-0.013*	-1.123***	-1.027***	-1.503***
	(0.006)	(0.006)	(0.007)	(0.315)	(0.348)	(0.434)
GDP growth$_{(t-1)}$	-6.158***	-5.210***	-5.122**	-5.338	-5.222	-12.185***
	(1.615)	(1.795)	(2.009)	(4.434)	(4.458)	(4.109)
incidence comm. violence$_{(t-1)}$	0.010***	0.010***	0.010***	0.050***	0.050***	0.045***
	(0.001)	(0.001)	(0.002)	(0.013)	(0.013)	(0.014)
Sub-regional fixed effects	No	Yes	Yes	No	Yes	Yes
Time fixed effects	No	No	Yes	No	No	Yes
Obs	1181	1181	1181	453	453	453
Pseudo-R^2	0.0620	0.0657	0.0744	0.0854	0.0860	0.1336
AIC	1749.23	1748.43	1748.27	460.54	462.27	455.21
BIC	1794.9	1809.32	1849.75	497.59	503.43	529.30

Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Note: Panel negative binomial regression coefficients with standard errors clustered at country level in parentheses.

our perspective, correspond to a significant reduction in the number of events, supporting the argument that narrower livelihoods essentials constitute a major threat for communal groups.

5.4 Additional estimations

As a final step of the analysis, we tested our results controlling for additional factors that may affect the outbreak of communal violence[5]. Estimation details are described in the Supplementary Materials, whereas Tale 3 depicts a summary of the effects.

First, we considered the possible religious characterization of previous communal violence since, in that case, the hypothesized transmission mechanism (namely, the undermining of livelihoods due to climate vulnerability) might be weaker. Using UCDP-GED information about conflict actors we derived corresponding controls.

Then, although communal violence is likely to be disconnected from direct electoral dynamics, elites might attempt to manipulate ethnic or religious cleavages - whose identity component defines communal groups - for electoral benefits and thus fuel communal violence (Birch, Daxecker & Höglund, 2020). Therefore, using information gathered from the Deadly Electoral Conflict Dataset (Fjelde & Höglund, 2022), we introduced an additional control for previous electoral violence.

[5]Among them, population density is considered a possible driver of (communal) violence. Nonetheless, we preferred to exclude this dimension as in our sample it is highly correlated with forest share and per capita agricultural land, that is the variables measuring potential access to productive means in our analysis. This operational choice aims to keep the analysis structure consistent with the key argument proposed. It is worth noting that the vulnerability index includes multiple demographic dimensions accounting for population size.

Table 3: Additional estimations

control variable	Coefficient of control variables				Coefficient of vulnerability index			
	Likelihood		Severity		Likelihood		Severity	
	SSA	S-SEA	SSA	S-SEA	SSA	S-SEA	SSA	S-SEA
relig. violence$_{(t-1)}$	0.379*	-1.006***	1.208***	-0.139	1.332***	2.645	0.615*	1.465
incidence relig. viol.$_{(t-1)}$	0.307**	-1.083***	1.396***	-0.341	1.343***	2.303	0.567*	1.376
electoral violence$_{(t-1)}$	0.262	0.391	0.322**	0.637	1.334***	1.741	0.541	1.750*
discrim. groups$_{(t-1)}$	0.281	-0.891	0.233	-1.440***	1.282**	3.164	0.589*	2.762***
share discrim. pop.$_{(t-1)}$	0.018**	-0.174*	0.002	-0.302***	1.294**	2.638	0.625*	3.306***

Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Only coefficients of additional control variables and main parameter of interest are shown. All variables are temporally lagged to avoid reverse causality.

Following Brosché (2023), we finally explored whether a government bias disfavouring specific groups in a country impacts on communal violence. We operationalized it by controlling for the existence of discriminated groups and the corresponding population share. We used data from the Ethnic Power Relations database for this purpose (Vogt et al., 2015). Interestingly enough, once discriminatory policies are accounted for, vulnerability to climate change turns significant in S-SEA, suggesting heterogeneous effects according to power distribution among groups. This relation opens areas of further research.

In general, the additional estimations corroborate the idea that vulnerability to climate change sustains large-scale regional patterns, being a primary driver of communal violence in Sub-Saharan Africa.

To verify the consistency of results, we performed a set of robustness analyses, including models' re-estimation with time polynomials to model time dependence and sample reduction to mitigate overdispersion. We further tested whether our results about the role of vulnerability to climate change in Sub-Saharan Africa are robust to the exclusion of religious events.

Overall, the main findings are confirmed providing support to our argument (details are provided in Section B4 of the Supplementary Materials), in particular as far as regards the likelihood of communal violence, which appears to be the dimension most consistently explained by the estimation models.

6 *Conclusions*

This paper contributes to the climate-conflict debate by analysing geographically diversified patterns and linking the vulnerability to climate change to the likelihood and severity of events of communal violence in Sub-Saharan Africa and South/South-East Asia. By making use of a longitudinal setting of analysis covering the period 1995-2021, we found that higher vulnerability - proxied by the ND-GAIN Vulnerability Index - is conducive to a higher likelihood and severity of communal violence in Sub-Saharan Africa (SSA), whereas in South/South-East Asia (S-SEA) we did not find meaningful correlations.

From a methodological perspective, we would claim the relevance of two elements. First, we focused the analysis on communal violence - that is deadly armed events involving non-state actors whose mobilization is based on identity lines 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 choice enables us to test our hypothesis from a broader geographical perspective, allowing us to identify regional-specific patterns of the conditional effects of climate change on communal violence.

Throughout the analysis, African countries report a 0.536 average vulnerability score, associated with an increase of almost 18% probability of communal violence outbreak. The results point out the relevance of vulnerability to climate change in terms of social stability within this area. Greater levels of vulnerability, in fact, are also associated to higher communal violence severity. On the other hand, S-SEA results suggest that current climate variability (measured as negative rainfall deviations within the period) exerts a greater effect on communal violence outbreaks than overall vulnerability to climate change.

In general, greater access to productive means and livelihood essentials - which is measured by agricultural land over rural population size - is consistently conducive to a reduction of the likelihood as well as the severity of communal violence.

Our findings, which are robust to various alternative specifications, can inform the design of policies in different areas. They underscore the need for an integrated approach that combines climate policies with efforts to maintain social stability. We argue that climate decision-making should move beyond a single-area approach to understand regional variations. In Sub-Saharan Africa, policy efforts to reduce vulnerability to climate change and promote forest-based mitigation initiatives can contribute not only to increase resilience but also to reduce communal violence. In South/Southeast Asia, current climate variability is likely exacerbating communal violence by undermining agricultural capacities and livelihoods. Therefore, targeting this sector can help reduce tensions and promote stability.

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APPENDIX

This document provides the following additional information: variables description (Table A1); regional summary statistics (Table A2); correlations, by region (Table A3); list of countries included in the analysis, along with country-specific information on communal violence occurrence and vulnerability to climate change (Table A4 and A5).

Table A1: Variables description

Variable	**Description**	**Data Source**
communal viol.	Occurrence of at least one event of communal violence (binary: 0,1)	UCDP-GED
num. viol. events	Yearly number of events of communal violence (count data)	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
agri.land/rural pop.	Agricultural land over rural population size (square km/thousand people)	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
GDP growth	GDP growth rate	WDI
incidence comm. viol.	Yearly number of events of communal violence over land size (number of events/millions sqkm)	UCDP-GED and WDI
Additional variables:		
religious	Occurrence of at least one event of religious communal violence (binary:0,1)	UCDP-GED
religious ratio	Number of religious events over total number of events (continuous)	UCDP-GED
electoral violence	Occurrence of at least one event of electoral violence (binary:0,1)	Deadly Electoral Conflict Database (DECO)
discrim. group	Existence of at least one discriminated group (binary:0,1)	Ethnic Power Relations (EPR)
share discrim. pop.	Share of discriminated population over total population (%)	Ethnic Power Relations (EPR)

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 violence	1280	.175	.380	0	1	486	.088	.284	0	1
num. viol. events	1280	2.790	12.229	0	235	486	1.098	5.332	0	59
vulnerability	1269	.535	.063	.384	.696	486	.497	.058	.359	.618
forest share	1280	32.60	24.78	.298	94.73	486	36.59	23.28	1.850	76.40
agri.land/rural pop.	1280	37.89	70.15	.369	351.31	486	5.889	6.403	.192	29.34
neg rainfall dev	1280	.394	.577	0	2.889	486	.399	.585	0	3.514
GDP growth	1231	.042	.072	-.460	1.499	471	.053	.051	-.334	.4174
incidence comm. viol.	1280	3.527	14.57	0	258.02	486	.782	3.904	0	58.37
religious	1280	.020	.141	0	1	486	.063	.244	0	1
religious ratio	1280	.010	.091	0	1	486	.055	.223	0	1
electoral violence	1280	.108	.311	0	1	486	.220	.414	0	1
discrim. group	1226	.203	.402	0	1	486	.497	.500	0	1
share discrim. pop.	1226	2.797	9.095	0	84	486	4.863	7.374	0	46.8

Table A3: Correlations

Sub-Saharan Africa	comm viol.	num.viol.event	vulnerab.	forest share	pc agri.land	neg.rainf.dev.	GDP growth	incid.comm.viol.
comm. viol.	1.0000							
num.viol.event	0.4943	1.0000						
vulnerability	0.2752	0.0398	1.0000					
forest share	-0.2464	-0.1060	-0.2462	1.0000				
pc agri.land	-0.0805	-0.0649	-0.1121	-0.1749	1.0000			
neg.rainf.dev.	-0.0230	-0.0077	0.0250	0.0098	0.0133	1.0000		
GDP growth	-0.0160	-0.0456	-0.0360	0.0644	-0.0429	0.0178	1.0000	
incid.comm.viol.	0.4880	0.6588	0.0428	-0.1376	-0.0753	0.0041	-0.0247	1.0000

South/South-East Asia	comm viol.	num.viol.event	vulnerab.	forest share	agri.land/rur.pop.	neg.rainfall dev.	GDP growth	incid.comm.viol.
comm viol.	1.0000							
num.viol.event	0.6620	1.0000						
vulnerability	0.0428	0.0244	1.0000					
forest share	-0.0704	-0.0416	-0.2313	1.0000				
agri.land/rur.pop.	-0.1530	-0.0980	-0.2065	-0.1767	1.0000			
neg.rainfall dev.	0.0941	0.0170	-0.0314	-0.0178	0.0258	1.0000		
GDP growth	0.0019	-0.0977	0.1589	0.1251	-0.0626	0.0335	1.0000	
incid.comm.viol.	0.4269	0.3448	0.0107	-0.0598	-0.0981	-0.0243	-0.0536	1.0000

Table A4: List of Sub-Saharan Africa countries and descriptive statistics

Sub-Saharan Africa, 1995-2021					
Country	Communal Violence	Events	Vulnerability Index Mean	St.Dev.	Overall Δ
Angola	no		.5012	.0051	.0138
Benin	no		.5633	.0047	-.0137
Botswana	no		.4531	.0222	-.0696
Burkina Faso	no		.5762	.0253	-.0690
Burundi	no		.5582	.0124	.0122
Cameroon	yes	4	.4707	.0050	-.0156
Cape Verde	no		.4418	.0118	-.0290
CAR	yes	111	.5797	.0075	.0142
Chad	yes	23	.6516	.0046	.0026
Comoros	no		.5452	.0115	-.0407
Dem. Rep. Congo	yes	303	.5703	.0045	-.0092
Equatorial Guinea	no		.4202	.0062	-.0127
Eritrea	no		.6058	.0142	.0162
Ethiopia	yes	326	.5634	.0148	-.0295
Gabon	no		.4457	.0075	-.0088
Ghana	yes	24	.4868	.0235	-.0536
Guinea	yes	9	.5430	.0097	-.0071
Guinea-Bissau	no		.6414	.0089	-.0231
Ivory Coast	yes	40	.4958	.0059	-.0090
Kenya	yes	503	.5294	.0101	-.0228
Lesotho	no		.4880	.0090	-.0307
Liberia	no		.6005	.0079	.0130
Madagascar	no		.5716	.0081	-.0195
Malawi	no		.5620	.0157	-.0419
Mali	yes	35	.6088	.0086	-.0286
Mauritania	no		.5695	.0082	-.0157
Mauritius	no		.4329	.0056	-.0055
Mozambique	no		.5005	.0074	-.0175
Namibia	no		.4828	.0118	-.2805
Niger	yes	7	.6356	.0130	-.0112
Nigeria	yes	1315	.5077	.0168	-.0494
Rep. of Congo	no		.5386	.0149	-.0304
Rwanda	no		.5600	.0194	-.0569
Sao Tome and Principe	no		.5256	.0074	-.0190
Senegal	no		.5356	.0128	-.0302
Seychelles	no		.4777	.0147	-.0471
Sierra Leone	no		.5645	.0057	-.0095
Somalia	yes	201	.6870	.0055	-.0131
South Africa	yes	1	.3933	.0056	-.0170
Sudan	yes	398	.6048	.0040	-.0111
Swaziland/Eswatini	no		.4946	.0111	-.0329
Tanzania	no		.5229	.0110	-.0304
The Gambia	no		.5593	.0100	-.0322
Togo	no		.5155	.0117	-.0394
Uganda	yes	90	.5891	.0057	-.0110
Zambia	no		.4896	.0070	-.0039
Zimbabwe	no		.5101	.0054	.0015

Table A5: List of South/South-East Asia (S-SEA) countries and descriptive statistics

Southern/South-Eastern Asia, 1995-2021					
Country	Communal Violence	Number of events	Vulnerability Index		
			Mean	St.Dev.	Overall Δ
Afghanistan	no		.6013	.0107	-.0279
Bangladesh	no		.5610	.0186	-.0554
Bhutan	no		.5276	.0086	-.0111
Cambodia	no		.5152	.0161	-.4159
India	yes	263	.5173	.0134	-.0415
Indonesia	yes	161	.4567	.0106	-.0338
Iran	no		.3846	.0108	-.0261
Laos	no		.4988	.0257	-.0708
Malaysia	no		.3729	.0085	-.0168
Maldives	no		.5568	.0273	-.0663
Myanmar	yes	25	.5164	.0090	-.0259
Nepal	no		.5228	.0264	-.0578
Pakistan	yes	76	.5341	.0105	-.0297
Philippines	yes	8	.4795	.0149	-.0379
Sri Lanka	yes	3	.4673	.0063	-.0003
Thailand	no		.4380	.0065	-.0103
Timor-Leste	no		.5276	.0158	-.0280
Vietnam	no		.4822	.0123	-.0272

B1 ND-GAIN Vulnerability to climate change index: components

The index is conceived as a function of three components: exposure, sensitivity, and adaptability, measured by multiple indicators across six life-supporting sectors.

Table B1: Structure of the ND-GAIN Vulnerability Index, by life-supporting sector and components

	ND-GAIN Vulnerability Index		
Sector	**Components**		
	Exposure	*Sensitivity*	*Adaptive capacity*
Food	Projected change of cereal yields	Food import dependency	Agriculture capacity (fertilizer,irrigation, pesticide,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 deaths from climate change induced diseases	Slum population	Medical staff (physicians, nurses,midwives)
	Projected change of in 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 and 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
	Projected change 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) using RCP 4.5 emission scenario. Original data source: Aqueduct, World Resource Institute. All other indicators are yearly measured.

B2 Definition of sub-regional areas

The empirical analysis envisages the use of sub-regional fixed effects to account for heterogeneity across countries within a same continuous geographical area. Sub-regions are defined according to the UN Geo-Scheme:

- Western Africa: Benin, Burkina Faso, Cape Verde, Ghana, Guinea, Guinea-Bissau, Ivory Coast
- Eastern Africa: Burundi, Comoros, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Seychelles, Somalia, Sudan, Tanzania, Zambia, Zimbabwe.
- Middle Africa: Angola, Cameroon, Central African Republic, Chad, Dem.Rep.Congo, Equatorial Guinea, Gabon, Rep. of Congo, Sao Tome and Principe.
- Southern Africa: Botswana, Lesotho, Namibia, South Africa, Swaziland/Eswatini.
- Southern Asia: Afghanistan, Bangladesh, Bhutan, India, Iran, Maldives, Nepal, Pakistan, Sri Lanka.
- South-Eastern Asia: Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Thailand, Timor-Leste, Vietnam.

B3 Additional Estimations

As explained in Section 5.4, we further extended the analysis by including some additional controls, whose description is provided in Table A1. Table B2 describes the results for the likelihood of events of communal conflict whereas Table B3 refers to the severity of communal violence. We apply the model specification including sub-regional fixed effects as reference model.

Results consistently confirm the role of vulnerability to climate change as triggering factor for the likelihood and - to a lesser extent - severity of communal violence in Sub-Saharan Africa, and bring some interesting suggestions on regional patterns. Throughout all stages of analysis we found support to the idea that in the Asian region the scarcity of productive means and climate uncertainty are those factors explaining communal violence to a large extent. However, when we control for the existence of discriminated groups in the country, the variable of main interest - vulnerability to climate change - turns significance with expected sign. This may suggest that vulnerability to climate change generates heterogeneous effects depending on the distribution of power between groups and therefore the existence of a government bias.

As far as regards the religious nature of the events, it should be noted that in Sub-Saharan Africa only 289 cases belong to this category (that is 8% of total events) and they occur in just two countries (namely, Nigeria and Central African Republic, the latter being characterized by religious events only). Their incidence is associated to a subsequent increase of communal violence, suggesting their amplifying role in a context of inter-groups competition. On the other hand, in South/South-Est Asia religious events represent the 51.7% of the total and broadly spread across India, Indonesia, Myanmar, Philippines and Sri Lanka, outlining quite a different scenario. Interestingly, in Asian sub-regions having experienced religious events appears to be negatively correlated with the likelihood of communal violence. This result may reflect a possible pacifying role of local religious institutions (see for example De Juan, Pierskalla and Vüllers, 2015) and the fact that religious events cover a large part of those that have occurred and they have been decreasing during the observation period. Nonetheless, this finding would deserve further investigations.

While electoral violence does not appear to be linked to the outbreak of communal violence, it is interesting to note that the severity of the phenomenon seems to be affected by this aspect in Sub-Saharan Africa. In other words, the possible political use of ethnic or religious cleavages between groups does not trigger violence but is capable of mobilizing groups with an amplifying effect once the violence has begun.

Finally, we found that the size of discriminated population is strongly related to communal violence; however, once again, large-scale regional patterns are identified. In Sub-Saharan Africa groups discrimination increase the likelihood of communal conflict, as expected. In South/South-East Asia the distribution of the variable is highly skewed and those countries characterized by large shares of discriminated population (i.e. Bhutan and Iran) do not experience any event of communal conflict. This feature might explain the negative correlation. The results relating to the total yearly number of events are consistent with this path.

Table B2: Additional estimations: likelihood of events of communal conflict

	Sub-Saharan Africa					South/South-East Asia				
vulnerability$_{(t-1)}$	1.332***	1.343***	1.334***	1.282**	1.294**	2.645	2.303	1.741	3.164	2.638
	(0.511)	(0.515)	(0.499)	(0.518)	(0.535)	(4.552)	(3.460)	(2.211)	(4.512)	(2.195)
negative rainfall deviations	-0.166	-0.166	-0.155	-0.174	-0.173	0.457***	0.437***	0.408***	0.491***	0.467***
	(0.130)	(0.131)	(0.128)	(0.133)	(0.127)	(0.138)	(0.144)	(0.156)	(0.182)	(0.180)
forest share	-0.063***	-0.064***	-0.063***	-0.062***	-0.068***	-0.017	-0.011	-0.002	-0.000	0.001
	(0.015)	(0.015)	(0.015)	(0.015)	(0.018)	(0.075)	(0.054)	(0.026)	(0.046)	(0.036)
pc agricultural land$_{(t-1)}$	-0.020***	-0.020***	-0.020**	-0.020**	-0.022**	-0.324*	-0.307*	-0.277*	-0.546	-0.450*
	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)	(0.178)	(0.162)	(0.144)	(0.685)	(0.232)
GDP growth$_{(t-1)}$	-2.836**	-2.842**	-2.929**	-2.757**	-2.917**	-1.502	-1.526	-2.792	-4.189	-4.413
	(1.381)	(1.374)	(1.361)	(1.312)	(1.318)	(4.639)	(4.494)	(3.902)	(5.236)	(4.648)
incidence comm. violence$_{(t-1)}$	0.087***	0.087***	0.088***	0.088***	0.088***	0.153***	0.150***	0.102***	0.107***	0.107***
	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.027)	(0.023)	(0.022)	(0.020)	(0.023)
relig. violence$_{(t-1)}$	0.379*					-1.006***				
	(0.206)					(0.352)				
incidence relig. violence$_{(t-1)}$		0.307**					-1.083***			
		(0.151)					(0.166)			
electoral violence$_{(t-1)}$			0.262					0.391		
			(0.200)					(0.329)		
discrim.groups$_{(t-1)}$				0.281					-0.891	
				(0.307)					(1.076)	
share discrim. pop.$_{(t-1)}$					0.018**					-0.174*
					(0.009)					(0.090)
Sub-regional fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs	1181	1181	1181	1136	1136	453	453	453	453	453
Pseudo-R^2	0.1839	0.1836	0.1857	0.1863	0.1900	0.2026	0.2070	0.1857	0.1924	0.2124
AIC	401.31	401.45	400.49	400.20	398.50	173.84	173.13	177.15	175.93	171.95
BIC	462.20	462.34	461.38	460.62	458.93	215.00	214.28	218.31	217.09	213.11

Table B3: Additional estimations: severity of events of communal conflict

	Sub-Saharan Africa					South/South-East Asia				
vulnerability$_{(t-1)}$	0.615*	0.567*	0.541	0.589*	0.625*	1.465	1.376	1.750*	2.762***	3.306***
	(0.335)	(0.335)	(0.337)	(0.335)	(0.345)	(0.941)	(0.941)	(0.956)	(0.979)	(1.038)
negative rainfall deviations	0.039	0.055	0.072	0.066	0.050	0.553***	0.549***	0.494**	0.536**	0.480**
	(0.111)	(0.115)	(0.114)	(0.115)	(0.115)	(0.210)	(0.211)	(0.212)	(0.225)	(0.221)
forest share	-0.018*	-0.018	-0.015	-0.015	-0.012	0.063***	0.065***	0.061***	0.066**	0.070***
	(0.011)	(0.011)	(0.010)	(0.011)	(0.010)	(0.024)	(0.024)	(0.023)	(0.026)	(0.027)
pc agricultural land$_{(t-1)}$	-0.014**	-0.013**	-0.014**	-0.012**	-0.015**	-1.050***	-1.084***	-0.980***	-1.012***	-1.122***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.354)	(0.358)	(0.352)	(0.350)	(0.369)
GDP growth$_{(t-1)}$	-6.761***	-7.040***	-5.720***	-4.836***	-5.156***	-5.257	-5.457	-8.244*	-10.978**	-13.262***
	(0.976)	(0.903)	(1.814)	(1.837)	(1.817)	(4.462)	(4.483)	(4.954)	(4.786)	(3.925)
incidence comm. violence$_{(t-1)}$	0.008***	0.011***	0.011***	0.011***	0.011***	0.051***	0.051***	0.043***	0.057***	0.057***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.013)	(0.013)	(0.013)	(0.014)	(0.013)
relig. violence$_{(t-1)}$	1.208***					-0.139				
	(0.327)					(0.358)				
incidence relig. violence$_{(t-1)}$		1.396***					-0.341			
		(0.389)					(0.402)			
electoral violence$_{(t-1)}$			0.322**					0.637		
			(0.141)					(0.394)		
discrim.groups$_{(t-1)}$				0.233					-1.440***	
				(0.210)					(0.497)	
share discrim. pop.$_{(t-1)}$					0.002					-0.302***
					(0.007)					(0.091)
Sub-regional fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	1181	1181	1181	1136	1136	453	453	453	453	453
Pseudo-R^2	0.0720	0.0708	0.0684	0.0673	0.0667	0.0863	0.0875	0.0915	0.1050	0.1221
AIC	1738.69	1740.96	1745.39	1747.41	1748.59	464.11	463.52	461.61	455.07	446.80
BIC	1804.65	1806.92	1811.35	1812.87	1814.05	509.39	508.79	506.88	500.34	492.07

B4 Robustness Analyses

To verify the consistency of our findings, we performed some robustness checks, whose outcomes are reported in Table B4 and B5.

As far as regards the likelihood of communal violence, we changed the estimation technique and re-estimated the models applying a probit link function with time polynomials to capture the time trend. Main results are confirmed in coefficients' sign and significance levels, underlining the validity of the vulnerability-communal conflict pattern previously described. Different large-scale regional patterns are also confirmed to be at play.

Table B4: Robustness checks. Likelihood of events of communal conflict (1995-2021)

	Sub-Saharan Africa		South/South-East Asia	
	(R1)	(R2)	(R4)	(R5)
vulnerability$_{(t-1)}$	1.572***	1.471***	-1.094	-1.047
	(0.520)	(0.526)	(0.843)	(0.917)
negative rainfall deviations	-0.151	-0.151	0.544**	0.543**
	(0.126)	(0.126)	(0.226)	(0.227)
forest share	-0.043***	-0.062***	-0.024	-0.031
	(0.013)	(0.016)	(0.024)	(0.022)
pc agricultural land$_{(t-1)}$	-0.017***	-0.020**	-0.302***	-0.316**
	(0.006)	(0.009)	(0.110)	(0.135)
GDP growth$_{(t-1)}$	-2.373**	-2.384*	-6.420	-6.452
	(1.202)	(1.227)	(4.116)	(4.086)
incidence comm. violence$_{(t-1)}$	0.087***	0.088***	0.084***	0.084***
	(0.021)	(0.021)	(0.029)	(0.028)
Time polynomials	Yes	Yes	Yes	Yes
Sub-regional fixed effects	No	Yes	No	Yes
Obs.	1181	1181	453	453
Pseudo-R^2	0.1812	0.1880	0.2854	0.2859
AIC	400.58	403.43	160.54	162.44
BIC	456.39	474.47	205.81	211.83

Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Note: models are estimated by a probit link function with time polynomials. Standard errors are clustered at country level and shown in parentheses.

As far as regards the severity of communal violence, we reduced the sample to those countries experiencing at least one violent event during the period of observation (Table B5). In this way, we are able to bring down the overdispersion parameter while maintaining a good variance, and work on a homogeneous set of countries, although the total number of observations heavily dropped.
Results essentially confirm the main findings (Table 2) and bring new evidence about the role of the vulnerability in S-SEA. Once we reduced the sample to the countries experiencing communal violence to some extent, we found that vulnerability to climate change contributes to increase the severity of the phenomenon. Nevertheless, availability of productive means and past experience of communal violence show up being most stable predictors of the cumulative number of events of communal violence.

A last robustness analysis refers to Sub-Saharan Africa (Table B6), where the role of vulnerability to climate change - our main variable of interest - is found steadily significant. Also in this case we adopted a reduction sample strategy to focus on those events not holding a religious characterization. Therefore, we then refined

Table B5: Robustness checks. Severity of communal violence, reduced sample (1995-2021)

	Sub-Saharan Africa			South/South-East Asia		
	(R1.1)	(R2.1)	R(3.1)	(R4.1)	(R5.1)	(R6.1)
vulnerability$_{(t-1)}$	0.717***	0.505*	0.576*	2.247**	2.186**	0.149
	(0.273)	(0.311)	(0.325)	(0.921)	(0.934)	(1.372)
negative rainfall deviations	0.027	0.035	0.081	0.534**	0.535**	0.565**
	(0.117)	(0.116)	(0.125)	(0.211)	(0.212)	(0.254)
forest share	-0.026***	-0.005	0.005	0.056***	0.062***	0.053**
	(0.007)	(0.010)	(0.011)	(0.016)	(0.021)	(0.026)
pc agricultural land$_{(t-1)}$	-0.018***	-0.012**	-0.008	-0.936***	-0.856**	-1.264***
	(0.006)	(0.006)	(0.007)	(0.326)	(0.370)	(0.423)
GDP growth$_{(t-1)}$	-6.466***	-5.465***	-5.636***	-6.770	-6.685	-13.485***
	(1.521)	(1.746)	(1.817)	(4.600)	(4.630)	(4.063)
incidence comm. violence$_{(t-1)}$	0.010***	0.011***	0.011***	0.049***	0.049***	0.045***
	(0.001)	(0.001)	(0.002)	(0.012)	(0.012)	(0.014)
Sub-regional fixed effects	No	Yes	Yes	No	Yes	Yes
Time fixed effects	No	No	Yes	No	No	Yes
Obs	419	419	419	156	156	156
Pseudo-R^2	0.0611	0.0688	0.0785	0.0801	0.0806	0.1221
AIC	1692.87	1685.12	1683.82	439.04	440.85	437.85
BIC	1729.21	1733.58	1764.58	466.49	471.34	492.75

Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Only those countries experiencing at least one event of communal violence during the period of observation. All models show standard errors clustered at country level in parentheses.

the estimate by focusing the analysis on those events that should be in line with our argument.

Empirical evidence supports the robustness of our findings as regards communal violence likelihood. The greater the vulnerability to climate change, the greater the likelihood that communal violence will erupt due to the growing insecurity over livelihood systems and the mobilizing effect on groups competing for scarce resources. Regarding the severity of community violence, the results are almost confirmed, although the estimation models lose some significance, suggesting that our models better explain communal violence incidence rather than severity.

Table B6: Robustness checks: non-religious events, Sub-Saharan Africa (1995-2021)

	Sub-Saharan Africa					
		Likelihood			Severity	
	(R1.2)	(R2.2)	R(3.2)	(R1.3)	(R2.3)	(R3.3)
vulnerability$_{(t-1)}$	1.389***	1.370***	1.460***	0.819***	0.514	0.759**
	(0.504)	(0.507)	(0.550)	(0.296)	(0.347)	(0.366)
negative rainfall deviations	-0.142	-0.132	-0.118	0.116	0.116	0.149
	(0.136)	(0.134)	(0.159)	(0.113)	(0.113)	(0.121)
forest share	-0.048***	-0.060***	-0.063***	-0.026***	-0.021*	-0.015
	(0.014)	(0.013)	(0.015)	(0.007)	(0.011)	(0.012)
pc agricultural land$_{(t-1)}$	-0.018***	-0.019***	-0.020**	-0.019***	-0.015***	-0.017***
	(0.006)	(0.007)	(0.010)	(0.006)	(0.006)	(0.007)
GDP growth$_{(t-1)}$	-2.711*	-2.705*	-1.829	-2.507	-2.639	-1.312
	(1.576)	(1.572)	(1.525)	(1.638)	(1.630)	(1.829)
incidence not relig. violence$_{(t-1)}$	0.084***	0.085***	0.091***	0.011***	0.011***	0.011***
	(0.019)	(0.019)	(0.020)	(0.001)	(0.001)	(0.002)
Sub-regional fixed effects	No	Yes	Yes	No	Yes	Yes
Time fixed effects	No	No	Yes	No	No	Yes
Obs	1181	1181	1181	1181	1181	1181
Pseudo-R^2	0.1668	0.1708	0.2027	0.0573	0.0598	0.0690
AIC	377.51	381.78	383.93	1638.65	1640.47	1640.57
BIC	418.10	437.60	480.34	1684.32	1701.36	1742.06

Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Only non-religious events of communal violence are considered. Past incidence of events of communal conflicts refers to non religious violence only. All models show standard errors clustered at country level in parentheses.

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