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Vulnerability to climate change and communal conflicts: uncovering pathways

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Abstract

This research work provides new evidence about the effect of vulnerability to natural hazards on the likelihood of communal violence, by disentangling regional-specific pathways. We focus on Sub-Saharan Africa (SSA) and Southern/South-Eastern Asia (S-SEA) for the period 1995-2016, being these regions particularly exposed to climate effects and dominantly characterized by rain-fed and climate-sensitive agriculture. Relying on the ND-GAIN Vulnerability Index as multidimensional measure of 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. This result is consistent across the regions, and it remarks the fragility of SSA where levels of vulnerability are higher than those observed in S-SEA, on average. Overall, results suggest that policy efforts aimed at reducing vulnerability to natural hazards are powerful tools not only to make societies more resilient, but also more peaceful.

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

JEL: D74, O13, Q54, Q56

Vulnerability to climate change and communal conflicts: uncovering pathways

1 Introduction

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

The study of the effects of rainfall anomalies over the risk of civil conflict provides an example. Rainfall abundance 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 rainfall abundance 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), providing support to the environmental scarcity argument. According to it, shortages of food, water or crops import might generate stress in institutional and economic settings, which can be translated into social instability, especially in agriculture-dependent societies.

Such heterogeneity of results can be explained by the existence of multiple climate-conflict pathways, rather than a single causal chain, as well as qualitatively different conflict typologies. Empirical findings about the climate-conflict nexus may diverge since studies focus on different kind of conflicts, diverse geographical areas, and apply heterogeneous methodological approaches (Nordkvelle et al. 2017, 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 of specific locations across time to get 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 variability 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), fuelling human displacement and increasing the probability of inter-group conflicts (Hodler & Raschky 2014, Hegre et al. 2016), especially in case of marginalization. Within this scenario, population growth and weak institutional settings - common characteristics of Low and Middle Income Countries - can feed grievances and reinforce multidimensional inequalities, amplifying the negative impacts generated by economic disruptions and, thus, making violence outbreak more likely.

However, it is worth stressing that the magnitude of climate change effects largely depends on the same socio-economic structures of a country and, in particular, to the degree of vulnerability to climate hazards. A complex twine of factors ranging from geographic location and environmental features to social and economic conditions, including uneven development processes, defines to what extent a country is vulnerable to climate variability (IPCC 2014). Grounded on the research outcomes on natural hazards affecting human structures and communities (Janssen et al. 2006), the concept of vulnerability to climate change is currently outlined as a function of three components: exposure, sensitivity, and adaptive capacity (Weißhuhn et al. 2018). 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.

We argue that analysing the vulnerability to natural hazards allows capturing indirect and conditional effects of climate change on conflict risk.

Climate variability rises uncertainty over access to natural resources - especially land, water and forests, which ground the livelihoods of many communal groups. Given the hypothesis of conditional effects on conflict risk through socioeconomic changes, we decided to focus the analysis on communal conflicts only. This methodological choice is consistent with empirical literature about the climate-conflict nexus. 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, defined by a collective identity, for example, ethnic lines. (Sundberg et al. 2012). Communal violence is likely to rise as a result of inter-group increased competition over livelihoods means, resources and local power, especially in case of socioeconomic marginalization of specific groups (Hillesund 2019). 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.

In this study, we investigate how variations in vulnerability to climate hazards affect communal violence, accounting for socio-economic factors which might influence this relationship. We analyze Sub-Saharan Africa (henceforth: SSA) and Southern/South-Eastern Asia (henceforth: S-SEA), being these regions particularly exposed to climate effects and dominantly characterized by rain-fed and climate-sensitive agriculture.

Throughout multiple specification models, we found strong evidence that greater vulnerability makes the occurrence of communal violence more likely. Moreover, regional specific context shapes partially differentiated pathways, suggesting the existence of multifaceted mechanisms.

2 Data description

2.1 Communal violence

Communal violence refers to armed events involving non-state groups that are organized along collective identity lines, such as ethnic or tribal. We relied on data gathered from UCDP Geo-referenced Event Dataset (UCDP-GED) (Sundberg & Melander 2013, Croicu & Sundberg 2015) and merged with the Non-State Conflict Dataset to identify all violent events recognizable as expression of communal violence (Sundberg et al. 2012). The outbreak of individual events of communal violence is operationalized as a dichotomous variable. In this paper, we interchangeably use the terms communal conflict and communal violence to indicate an armed event responding to the definition provided above, and having produced at least one death.

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). Just to mention a few, conflicts between the Turkana and Pokot pastoralist communities in northern Kenya, as well as farmer–herder conflicts in the Sahel belt in Nigeria, 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)). Nevertheless, Asian countries report multiple and deadly events, although quite limited in number and geographical scope, which deserve to be further explored. 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).

This article contributes filling this gap by providing new empirical evidence about the likelihood of communal violence in Southern/South-Eastern Asia. The analysis of this region - highly exposed to climate hazards, and characterized by socio-political structures different from African societies - might help distinguishing regional-specific causal pathways disentangling conditional effects of climate variability on political violence.

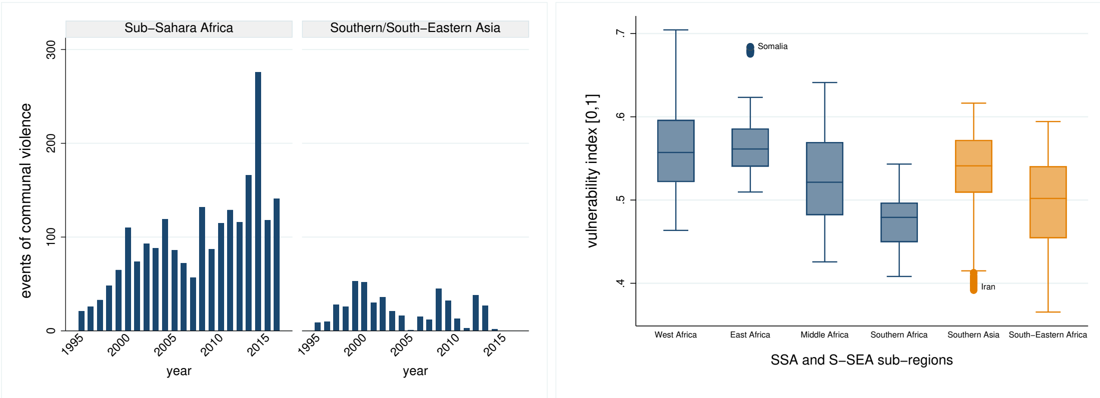

Figure 1: **Communal violence and vulnerability index.** Left-hand panel shows the number of events of communal violence across Sub-Saharan Africa and Southern/South-Eastern Asia (1995-2016). Right-hand panel shows median, 1st and 3rd quantiles of vulnerability index by sub-region. Whiskers indicate 95% confidence interval.See Table A3 and Table A4 in supplementary material for country-specific information about communal violence incidence and vulnerability index scores.

2.2 Vulnerability to climate hazards

Vulnerability to climate hazards represents the primary dimension of analysis. Given its multidimensional nature, we decided to adopt an holistic measure in order to address it in a comprehensive way. We rely on the ND-GAIN Vulnerability Index which, including both social and ecological components across six different life-supporting sectors, describes the comparative resilience of countries to climate change (Chen et al. 2015). This index is an established metric used by scholars as well as policy makers to explore challenges and adaption opportunities associated with climate uncertainty (Hendrix 2017, Grecequet et al. 2017, Chen et al. 2018).

The ND-GAIN index measures vulnerability as the propensity or predisposition of human societies to be negatively impacted by climate hazards. The index considers six life-supporting sectors: food, water, health, ecosystem services, human habitat and infrastructure, which are measured across the three cross-cutting dimensions of exposure, sensitivity and adaptive capacity. The selection of both dimensions and sectors is consistent with those identified by IPCC (Edmonds et al. 2020). Vulnerability in each sector 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 (Table A5 in the supplementary material illustrates the index structure). The index scores are normalized on [0,1] with higher values expressing greater vulnerability.

On average, vulnerability to climate hazards is pretty high in both regions. Sub-Saharan Africa appears particularly susceptible to the effects of a changing climate, with an overall score of 0.5423. Higher score values are reached in the Sahel and central-eastern tropical sub-region, although large variations apply (Figure 1). As far as regards S-SEA region, overall vulnerability score is slightly lower (0.5109), but also in this case we found a large country-specific variance. In particular, southern countries - such as Pakistan, India, Bangladesh - report higher vulnerability with respect to other countries within the same region (Figure 1). Since Somalia and Iran stand up as possible outliers, we tested the robustness of the empirical analysis by controlling for these countries (see Table A7 in supplementary material for robustness checks).

Looking at yearly changes in the index score, we noticed a consistent higher number of countries reporting a reduction of vulnerability respect to the number of countries facing a worsening in both regions (Table 2). Although this pattern sounds encouraging, the number of countries deteriorating their condition as well as vulnerability levels remain high, especially in Sub-Saharan Africa.

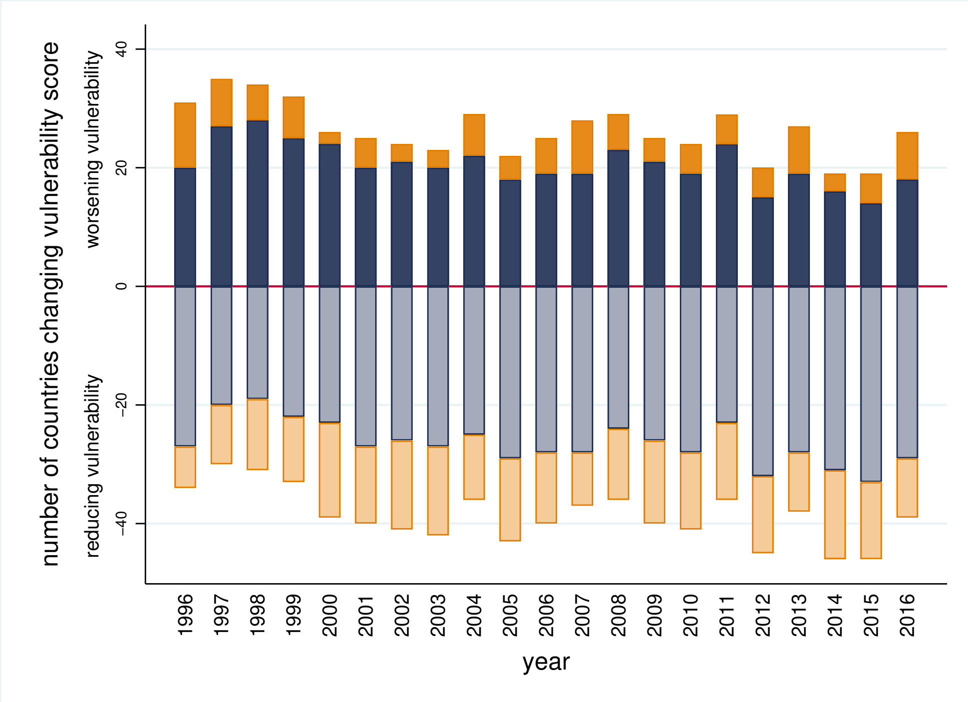

Figure 2: **Number of countries experiencing a change in the vulnerability index, by year.** Bars illustrate the total number of countries reporting a positive yearly variation of the score (= worsening of vulnerability, darkest shades) and negative yearly variation of the score (= reduction of vulnerability, lightest shades). Blue section refers to Sub-Saharan African countries, whereas orange section refers Southern/South-Eastern Asian countries.

Considering the whole period of analysis (1995-2016), 14 countries in SSA (out of the 46 included) increased their level of vulnerability towards climate hazards, with an average worsening of 1.7% in the index score. The Gambia and Central African Republic are the countries whose vulnerability worsened more. In both cases, a deficient agricultural capacity (which reflects a country's ability to acquire and deploy agriculture technology) largely drove the worsening, highlighting the critical role played by agrarian systems and food production to make societies more resilient to climate change (Buhaug et al. 2015). As far as regards S-SEA, almost all countries reduced own vulnerability towards climate hazards (-2.5% on average across the whole region). 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, the especially low adaptive capacity, associated with a still prevalent poverty, and the geographic location make the country particularly exposed to the effects of climate change.

2.3 Other controls

In addition to country vulnerability to climate change, other factors are likely to contribute to communal violence outbreak. More specifically, we argue that changes in forest areas, rainfall anomalies and economic performance may impact on conflict propensity in a diversified way according to the overall vulnerability level of a country. 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 groups, forests help stabilise the climate, regulate ecosystems, protect biodiversity, and are integral part in the carbon cycle. For this reason, our model includes a measure of forestry land use - namely the surface covered by forests, expressed in hectares - to control for deforestation (and conversely afforestation) at country level. We gathered data from FAOSTAT.

Although results about the link 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)). Whilst the vulnerability index adopted in this study embraces a comprehensive measure of current and foreseen water availability, observed precipitation anomalies are unaccounted. Therefore, we included a variable measuring the deviation of total yearly precipitations respect to average precipitations' level over the period 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 build the control variable.

Among the most robust correlates of civil conflict, poor economic performance and large populations stand out as primary triggers of violence outbreak. Weak socio-economic development undermines the relations of economic dependence between different social groups, increasing grievances and reducing the opportunity-cost of joining a rebellion (Collier & Hoeffler 2004, Fearon & Laitin 2003). Since the vulnerability index is highly correlated with GDP levels by construction (it includes several indicators of adaptive capacity which mainly depend on the country economic performance), we included the GDP growth rate to account for economic performance in a temporal perspective. Original data are gathered from World Bank WDI. Conversely, we did not control for population size, since this factor is already accounted for by the vulnerability index (Table A5).

Descriptive statistics about forest areas, rainfall anomalies and GDP growth rate are reported in Figure 3 and Figure 4.

Finally, we include also a time-lag variable (one year) to control for prior experience of communal violence, being history of violence a major determinant of conflict incidence.

3 Empirical strategy

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 covering Sub-Saharan Africa and Southern/South-Eastern Asia for the period 1995-2016. The decision to concentrate the geographical scope of this study on such regions grounds on multiple reasons. On the one side, both SSA and S-SEA are subject to communal violence and they are classified particularly vulnerable to climate change (Schleussner et al. 2018). Vulnerability to climate change is uneven 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 Southern/South-Eastern Asia are among those identified. On the one hand, these characteristics outline broad similarities to analyze the determinants of communal violence. On the other hand, the source of vulnerability to climate hazards might be embedded in context-specific features whose difference can contribute to uncover distinct causal pathways of communal violence.

The list of countries included in the analysis, complete of details about incidence of communal violence and vulnerability scores, is provided in Table A3 and Table A4 in the supplementary material section.

To substantiate our research hypothesis, the first stage of analysis is devoted at exploring the correlation pattern between the incidence of communal violence and vulnerability to climate hazards. As second step, we developed a statistical model of risk of communal violence across the two selected regions. 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 areas, rainfall anomalies, GDP growth and previous occurrence of communal violence. To control for heterogeneity, regional fixed effects are included in all models and standard errors are clustered at country level. Further, 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 replaced the measure of rainfall anomalies with intra-annual precipitation deviation, and third we controlled for possible outliers.

4 Results and discussion

Descriptive insights suggest some consistent regional pathways, although communal violence erupted in diversified climatic and socio-economic contexts. In SSA, a higher number of events of communal conflicts occurred where vulnerability to climate hazards is greater (Panel (B) in Figure 3). There, 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 descriptive result corroborates our research hypothesis.

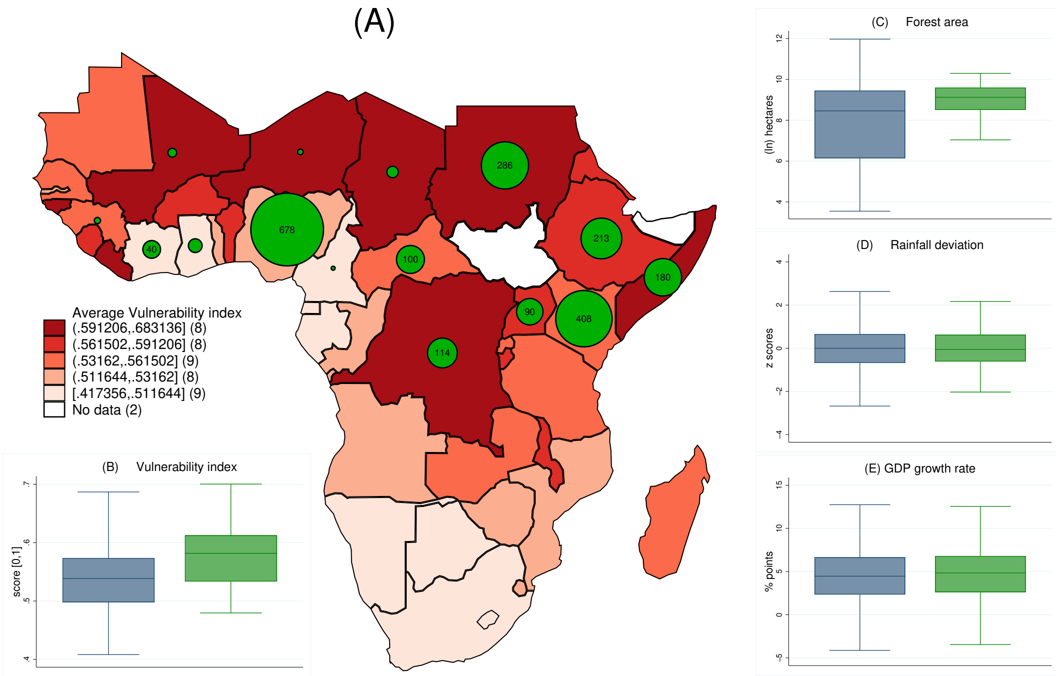

Figure 3: **Vulnerability index and incidence of events of communal violence in Sub-Saharan Africa.** Left-hand panel **(A)** illustrates average vulnerability country levels over the period 1995-2016 and the occurrence of events of communal violence. - Darkest shades refer to greater vulnerability and green circles are proportional to the absolute number of events. Box-plots show median, 1st and 3rd quantiles of **(B)** vulnerability index, **(C)** forest areas, **(D)** rainfall deviations and **(E)** 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)** and **(C)** at prob $|z| < 0.001$.

In S-SEA the same correlation pattern appears weaker (Figure 4): a case such as Indonesia, for example, suggests a less straightforward association between communal violence and vulnerability.

Interestingly, we found strong evidence that, in both regions, the existence of large forest areas which cover the national territory is meaningfully associated with communal violence (Panel (C) in Figure 3 and 4). This correlation is particularly noteworthy as far as regards S-SEA region, where efforts towards climate mitigation through afforestation initiatives are significant (see, for example, the REDD+ framework). Controversial impacts of these kind of initiatives include the disruption of local peoples' livelihoods and socio-cultural systems, unequal benefit sharing mechanisms, food insecurity, illegal land acquisitions and land-use change (Bayrak & Marafa 2016).

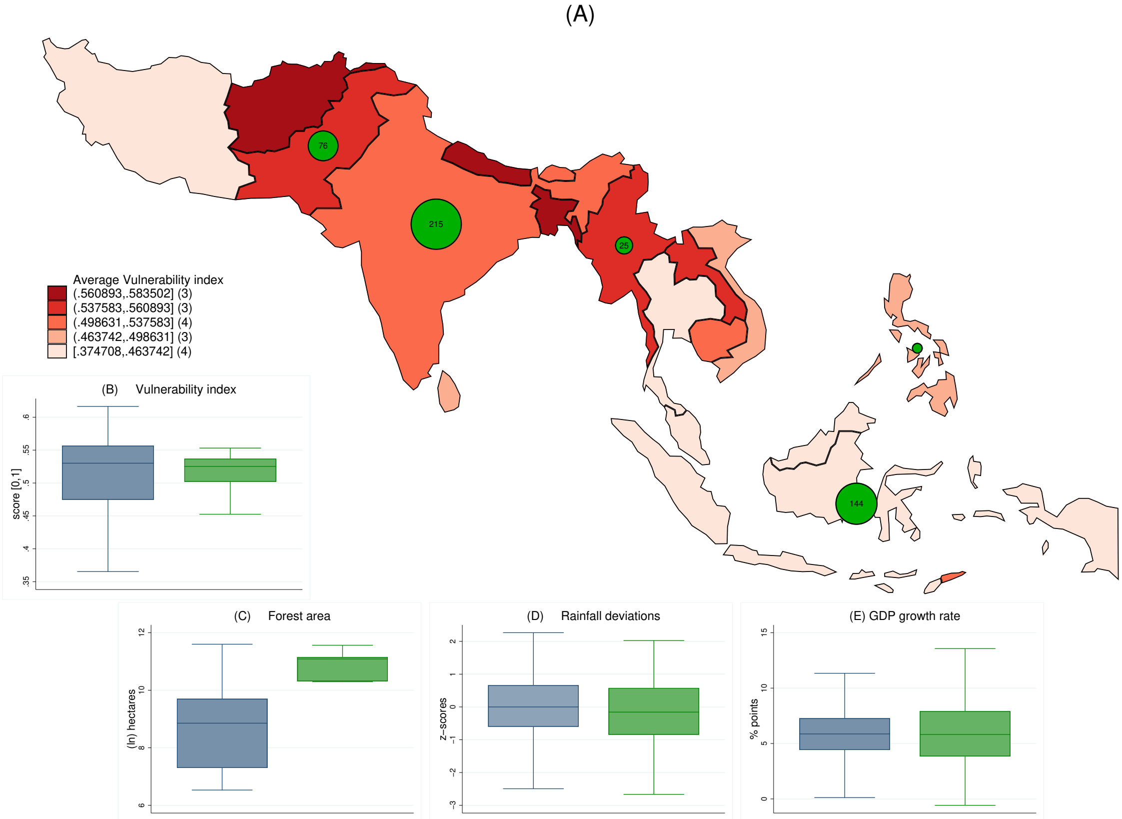

Figure 4: **Vulnerability index and incidence of events of communal violence in Southern/South-Eastern Asia.** Central panel **(A)** illustrates average vulnerability country levels over the period 1995-2016 and the occurrence of events of communal violence. Darkest shades refer to greater vulnerability and green circles are proportional to the absolute number of events. Box-plots show median, 1st and 3rd quantiles of **(B)** vulnerability index, **(C)** forest areas, **(D)** rainfall deviations and **(E)** GDP growth rate for respectively countries not characterized by communal conflicts (blue) and experiencing communal violence (green). The two groups significantly different in **(C)** only.

At a glance, it seems that rainfall anomalies do not depict different scenarios between country/year peaceful observations and those characterized by communal violence. A similar consideration can be drawn for GDP growth rate: descriptive statistics provided by panel (E) in Figure 3 and 4 do not seem suggesting any clear relation.

Once we came to the empirical analysis, we found robust evidence that vulnerability to climate hazards predicts the risk of communal violence (Table 1). However, as suggested by the preliminary descriptive analysis, a geographical pathway emerges: higher vulnerability increases the likelihood of communal violence in Sub-Saharan Africa, whereas in S-SEA region it reaches statistical significance when controlling for other covariates only. In this regard, forests seem to play a key role. We found that the risk of communal violence increases as forest areas expand. This finding might be explained through multiple mechanisms. First, forests have long provided armed groups with hiding places and lucrative funding sources (through illegal logging) largely used to sustain conflicts' costs and reward groups' members with forest-rich land. Second, forests (as common-pool resources) are a free-for-all resource subject to competition and over-exploitation. When property and use rights are not properly defined (hence, land-related institutional frameworks are weak), conflicting interests among competitive groups depending on forests are likely to rise and fuel clashes. Third, as already mentioned, changes in land use - even when deriving from afforestation initiatives - can irremediably impact on traditional livelihoods, making the opportunity to join a fighting group less costly.

Our result do not provide support to the idea that rainfall anomalies contribute triggering 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. According to FAO data (2020), rain-fed agriculture accounts for 60-65% of agricultural land in Southern and Eastern Asia. Within this percentage there are included both agro-pastoral systems, characterized by low productivity, and rice-based systems which reach high productivity but suffer from gradually more fragile ecosystems, growing occurrence of extreme weather events and pollution (Dubois et al. 2011). In both scenarios, rainfall abundance contributes to make such economic systems of production working, increasing economic opportunities and making conflict less likely.

On the other hand, and in the same line of reasoning, higher GDP growth rate reduces the likelihood of communal violence in SSA.

Across all models, we find strong evidence that communal violence show high temporal recurrence: in fact, having experienced events of communal conflict in the past increases the probability of occurrence. This result confirms a well-established evidence in the conflict literature. Further, it is interesting to underline that the persistence of communal violence has not only a temporal dimension, but also a spatial one, remaining the number of affected countries quite limited and consistent throughout the period considered.

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

	Sub-Saharan Africa			Southern/South-Eastern Asia		
	(1)	(2)	(3)	(4)	(5)	(6)
vulnerability index$_{(t)}$	1.430**	0.938**	1.306**	2.230	1.028**	1.234**
	(0.586)	(0.427)	(0.594)	(2.182)	(0.478)	(0.608)
(ln) forest land$_{(t)}$		0.412***	0.620***		0.722**	0.870***
		(0.148)	(0.178)		(0.281)	(0.320)
rainfall deviation$_{(t)}$		0.041	0.043		-0.210***	-0.468**
		(0.090)	(0.127)		(0.061)	(0.186)
GDP growth rate$_{(t-1)}$		-0.051***	-0.060***		-0.012	-0.010
		(0.014)	(0.019)		(0.038)	(0.042)
communal conf. event$_{(t-1)}$		1.123***	1.154***		0.951***	1.402***
		(0.274)	(0.279)		(0.352)	(0.217)
constant	-24.424***	-20.901***	-23.475***	-14.948	-14.256***	-18.676***
	(8.166)	(3.137)	(4.251)	(13.514)	(4.885)	(5.943)
Regional fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	No	No	Yes	No	No	Yes
Obs	1012	979	979	396	381	345
Countries	46	45	45	18	18	18
AIC	406	346	369	159	151	143
BIC	435	390	520	175	183	209

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Note: Panel probit regression coefficients with standard errors clustered at country level in parentheses. Regional fixed effects apply to all models. Time fixed effects apply to models (3) and (6) only.

The overall finding of the analysis is that vulnerability to climate change - understood in a broad sense that involves the interdependence between socio-economic and geographical components - explains the risk of communal violence. 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). Therefore, we calculated the predicted probabilities for the outbreak of events of communal conflicts given different levels of vulnerability. Results are plotted in Figure 5 and they refer to model (2) for SSA and to model (5) for S-SEA.

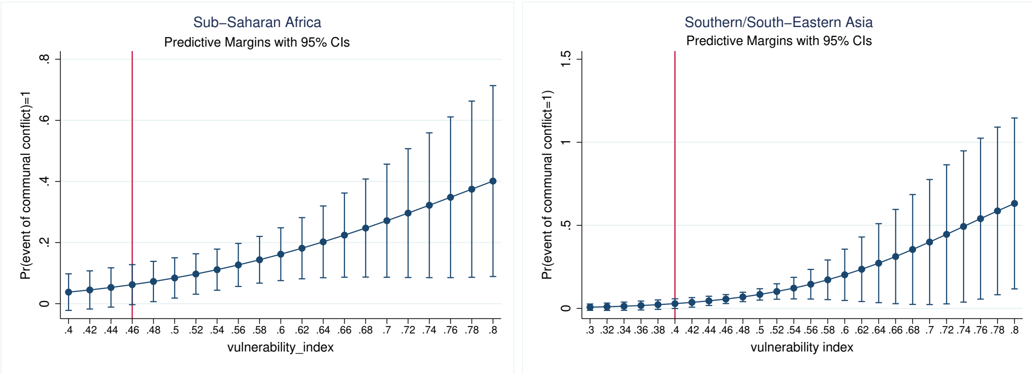

Figure 5: **Predicted probabilities of communal violence outbreak.** The charts provide predictive margins for communal violence occurrence at different values of the vulnerability index. The vertical red line indicates the lowest index score achieving statistical significance.

According to the outcomes of our analysis, in SSA a minimum score of 0.46 is sufficient to significantly increase the likelihood of 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). In S-SEA, the pathway is somehow different. Although a lower minimum score (0.4) significantly determines violence risk, impacts on communal conflict likelihood are almost equivalent to those observed in the African context for a large section of vulnerability scores. However, for greater scores (>=0.64), margins in S-SEA are larger. Nevertheless, it should be stressed that the worst performer in the region is Afghanistan, being ranked with a score of 0.58, on average, pretty far from such divergence threshold. Above all, the results clearly signal the increasing insecurity associated with a possible rise in the vulnerability score in terms of communal violence.

Finally, as explained in Section 3, we run some robustness checks by changing estimation technique, controls definition and sample size. They strongly confirm the reliability of the findings. Results are provided in Table A7 in supplementary material.

5 Conclusions

Within the climate-conflict nexus literature, a substantial consensus supports the argument that climate variability indirectly feeds social instability under specific conditions which make the effects of a changing climate disruptive. Among them, the prevalence of economic systems dependent on land and land-related resources (such as rain-fed agriculture) and low levels of development nourish the possibility that climate change generates effects on conflict risk.

Within this perspective, to what extent countries are overall susceptible to the effects of a changing climate matters. We argue that country vulnerability to natural hazards - being a complex intertwined connection between exposure, sensitivity and adaptive capacity - is a key determinant to explain violence occurrence. Our approach allows simultaneously considering multiple dimensions whose relations are characterized by causal intra-linkages and feedback loops.

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

Relying on the ND-GAIN vulnerability index and other socio-economic and climatic features gathered from multiple sources, we outlined a comprehensive picture of countries' susceptibility to climate change in these regions. Analysing the period 1995-2016, we found strong evidence that greater vulnerability is conducive to a higher risk of communal violence. Although a minimum degree of vulnerability is required to produce significant effects on conflict risk (0.46 for Sub-Saharan Africa, 0.40 for Southern/South-Eastern Asia in a 0-1 range), the majority of countries in both regions largely overcome such thresholds. We derive the conclusion that their vulnerability increases communal violence likelihood by making livelihoods more precarious and increasing competing interests over limited resources. Our results suggest that communal violence is deeply connected to land use (forests), and possibly activated by mechanisms of over-exploitation and claims generated by conflicting land uses. Although this result is consistent across the regions, it is worth remarking that it casts light on the fragility of SSA where levels of vulnerability are higher than those observed in S-SEA, on average.

Finally, communal violence is confirmed showing high persistence in time, since a prior experience of this form of socio-political instability is a major determinant for future recurrence.

From our findings - robust to a series of alternative specifications - we can derive some policy implications: i) policy efforts aimed at reducing vulnerability to climate hazards are powerful tools not only to make societies more resilient, but also more peaceful; ii) initiatives which determine land-use changes, even those aimed at mitigating the effects of climate variability such as afforestation projects, might eventually clash with customary uses and contribute to increasing social instability.

Supplementary material

This document present descriptive statistics of key indicators (and details on alternative model specifications that complement the results reported in the main article, namely:

- Table A1 provides variables description, including data sources;
- Table A2 provides regional summary statics;
- 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 illustrates the indicators used for the calculation of the vulnerability index;
- Robustness check: Table A6 provides the results of probit estimations with time polynomials of Models (1-2) for Sub-Saharan Africa and Models (4-5) for Southern/South-Eastern Asia;
- Robustness check: Table A7 provides the results of panel probit estimations of complete models substituting rainfall deviations with a control for intra-annual rainfall variation and, in Model R9, a reduced sample to control for Iran.

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 index	Vulnerability index to climate hazards (range: 0-1)	ND-GAIN
(ln) forest land	Surface covered by forest land (hectares, log transformed)	FAOSTAT
rainfall deviation	Deviation of total yearly precipitations from average level over the period (z scores)	CCKP-World Bank
GDP growth rate	GDP growth rate (% points)	WB
intra-annual rainfall dev.	Std.Dev. of yearly precipitations (std.dev.)	CCKP-World Bank

Table A2: Summary statistics, by region

	Sub-Saharan Africa				Southern/South-Eastern Asia			
	Mean	Std.Dev	Min.	Max.	Mean	Std.Dev.	Min.	Max.
comm_conf	.1679	.3740	0	1	.0959	.2949	0	1
vulnerability index	.5423	.0589	.4081	.7043	.5109	.0597	.365	.6163
(ln) forest land	8.158	2.100	3.545	11.97	8.431	2.448	0	11.59
rainfall deviation	-.006	1.000	-3.04	3.524	-.010	.9730	-3.36	2.754
GDP growth rate	4.768	7.511	-36.3	149.9	5.730	3.855	-13.1	26.11
intra-annual rainfall dev.	75.77	43.50	10.12	311.4	99.02	54.27	8.99	314.9
Observations	1012				396			

Table A3: List of 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
Sao Tome and Principe	no		0.5835	0.0075	-0.0053
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
Maldives	no		0.5765	0.0256	-0.0698
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

Note: Bold names indicate countries where communal violence occurred.

Table A5: Indicators used for the calculation of the vulnerability index

	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 international 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
	Projection of sea level rise impacts	Population living under 5 m above the sea	Disaster preparedness

Table A6: Robustness check - Likelihood of events of communal violence (1995-2016) estimated by probit link function with time polynomials.

	Sub-Saharan Africa		Southern/South-Eastern Asia	
	(R1)	(R2)	(R3)	(R4)
vulnerability index$_{(t)}$	0.515***	0.411**	0.039	0.589***
	(0.106)	(0.171)	(0.104)	(0.170)
(ln) forest land$_{(t)}$		0.198***		0.542***
		(0.052)		(0.128)
rainfall deviation $_{(t)}$		0.044		-0.225*
		(0.069)		(0.119)
GDP growth rate $_{(t-1)}$		-0.021*		-0.025
		(0.012)		(0.040)
communal conf. event$_{(t-1)}$		2.383***		1.341***
		(0.152)		(0.318)
constant	-8.585***	-9.683***	-1.807***	-10.168***
	(0.624)	(1.081)	(0.667)	(1.835)
Time polynomials	Yes	Yes	Yes	Yes
Regional fixed effects	Yes	Yes	Yes	Yes
Obs	1012	979	396	381
Countries	46	45	18	18
AIC	796	412	255	155
BIC	835	470	279	194

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

Note: Probit regression coefficients with standard errors clustered at country level in parentheses. Time polynomials and regional fixed effects apply to all models.

Table A7: Robustness check - Likelihood of events of communal violence (1995-2016) controlling for intra-annual precipitation deviation and potential outliers.

	Sub-Saharan Africa		Southern/South-Eastern Asia		
	(R5)	(R6)	(R7)	(R8)	(R9)
vulnerability index $_{(t)}$	0.765*	1.141**	1.235***	1.521**	0.973**
	(0.413)	(0.564)	(0.469)	(0.723)	(0.477)
(ln) forest land $_{(t)}$	0.408***	0.610***	0.724***	0.888***	0.696***
	(0.150)	(0.177)	(0.257)	(0.342)	(0.233)
intra-annual rainfall dev.$_{(t)}$	-0.007	-0.006	-0.008***	-0.011***	-0.008***
	(0.006)	(0.007)	(0.003)	(0.004)	(0.003)
GDP growth rate$_{(t-1)}$	-0.051***	-0.061***	-0.004	0.005	-0.005
	(0.014)	(0.019)	(0.041)	(0.045)	(0.042)
communal conf. event $_{(t-1)}$	1.141***	1.162***	0.889**	1.111***	0.897**
	(0.285)	(0.286)	(0.403)	(0.380)	(0.401)
constant	-17.117***	-23.225***	-14.321***	-18.330***	-12.662***
	(2.897)	(4.746)	(4.524)	(6.352)	(4.284)
Obs	979	979	381	345	359
Countries	45	45	18	18	18
AIC	347	360	151	146	151
BIC	396	492	183	211	182

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

Note: Panel probit regression coefficients with standard errors clustered at country level in parentheses. Regional fixed effects apply to all models. Time fixed effects apply to models (3) and (6) only.

Model(9) excludes Iran which is found as potential outlier in the descriptive analysis. As far as regards SSA, Somalia - other possible outlier - is never included in full models due to missing data on GDP.

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