Epidemiology of Violence in Colombia

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Abstract

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Armed conflict is a major cause of injury and death worldwide, posing a significant public health problem. In addition to mortality directly resulting from violence, armed conflicts indirectly cause morbidity and mortality through destruction of health infrastructure and diversion of resources, forced displacement, environmental damage to water/sanitation access, and erosion of social and economic security. Colombia's internal armed conflict began in the 1940s and was uniquely long-lasting, fractious, and geographically dynamic. By leveraging the spatial and temporal heterogeneity of Colombia's armed conflict, this study examines the spatial trends in violence (Aim 1) and estimates the impact of armed conflict on infant and child survival (Aim 3).

Contents

AIM 1

Spatial Analysis of Homicide and Armed Conflict in Colombia, 1990-2019

INTRODUCTION

Countries that have recently ended armed conflicts tend to experience a precarious period of post-conflict. In particular, internal armed conflicts (such as civil wars) fracture societies, weaken institutions, and may increase citizens' tolerance for violence in general.[1] Following a resolution or end to hostilities, state investment in humanitarian and restorative efforts, social unification, and institutional capacity are required to unify populations politically and (re-)instate institutional presence in areas affected by armed conflict, otherwise it is easy for fragile states to backslide into re-activating conflicts.[2] Interpersonal violence is an outcome with many drivers at the individual, community, and ecological levels; there are known structural causes of violence, including political, economic, social factors.[3,4] Spatial variation in violent death can be due to migration, changes in policy or jurisdictions, physical environment, or social features.[5] Temporal variation in violent death can be from economic changes, upheaval, changes in policy or law enforcement. Research on clusters of violence has increased lately because understanding geographical features of violence helps guide violence prevention and control.[6,7] Most studies of the spatial distribution of violence and crime have focused on Western countries.[8]

Colombia, a middle-income country of 55 million people, has coast lines along both the Pacific Ocean and Caribbean Sea, and connects Central America to South America via its border with Panama. Colombia also shares a very long and active border with Venezuela to the east, and borders Ecuador, Peru, and Brazil to the south. Colombia has experienced over 6 decades of internal armed conflict which has killed over 270,000 people.[9] While Colombia's armed conflict does not involve other states, it is also not a civil war, because there are multiple armed groups fighting the state and each other for different objectives.[10] One hallmark of Colombia's conflict is the dynamic spatiotemporal distribution of violence: armed guerrilla groups mostly concentrated in rural areas with geostrategic territorial features, with considerable movement over time.[11,12] The Colombian conflict was deadliest in the 1990s, due to the rise of narco-trafficking and mobilization of paramilitaries in the 1980s.[13,14] Between 1997-2002, there was a marked increase of violent deaths in rural, but not urban, areas in Colombia; a spatial analysis observed that the intensity of violence in rural areas during this time was associated with lower levels of poverty and higher levels of commercial agriculture in the affected municipalities, suggestive of an association between conflict intensity and regions rich in exploitable natural resources.[11,12] The geographic heterogeneity of Colombia's conflict has been a focus of political science studies, which have described the territorial appeal of rural regions to different actors, such as the presence of illegal economies or natural resources.[12]

Formally, Colombia's armed conflict ended in 2016 with the signing (and voter approval) of a peace treaty with the FARC, the most significant armed rebel group. The peace treaty aimed to de-mobilize the guerrilla group, grant conditional amnesty to former rebels who disarm and admit to any wrongdoing, and designated some parliamentary seats for a legitimized political party representing FARC interests.[15] However, the FARC is just one of the armed groups fighting the state of Colombia (and each other), and conflict-related events have escalated in the years since the Peace Treaty.[16] Rather than a final end to the armed conflict, some scholars and policy makers have described the period from 2017-present as simply another phase in Colombia's armed conflict.[17,18]

Homicides are formally defined as fatalities resulting from interpersonal violence between civilians, whereas armed conflict-related deaths are categorized as either deaths of combatants in the course of conflict between armed groups, or killings of civilians by armed groups.[11] Armed groups are traditionally recognized as rebel guerrilla groups, such as the Revolutionary Armed Forces of Colombia (FARC) in Colombia, but also include organized crime and narco-trafficking groups or cartels. The

United Nations Office on Drug and Crime (UNODC) includes deaths due to organized crime as non-conflict related intentional homicide, although the distinction is based on formal recognition of the space where the killing occurred as an active conflict zone.[19] In practice, it is quite difficult to separate conflict- and non-conflict related deaths because they can both be results of interpersonal violence.[20] In Colombia in particular, the distinction between homicide and armed conflict is blurred for two main reasons: First, the armed rebel group in Colombia's armed conflict that began with political ideologies became involved in international narco-trafficking as a means of fundraising, so some criminal groups are indistinguishable from guerillas.[21] Second, the selective assassinations of civilians by state-supported paramilitary groups were a defining feature of Colombia's armed conflict. Paramilitary groups such as the United Self-Defense Forces of Colombia (AUC) were known to falsely accuse civilians of supporting armed groups, frequently killing them and their families.[22] In March 2022, it emerged that Colombian paramilitary groups killed 6,402 civilians and falsely reported them as combatants, so-called "false positives".[23] Because of the difficulties disentangling homicide and armed conflict-related deaths, this dissertation will use the terms 'interpersonal violence' and 'violent deaths' to capture homicides and conflict-related deaths, excluding self-inflicted harm (suicide).

While the Americas region overall exhibits some of the highest homicide rates in the world, Colombia's rates of violent death are particularly striking.[24,25] Colombia's annual homicide rate was higher than that of any other country from 1990-1993, averaging 80 per 100,000 in that period.[26] The rate slowly decreased over time since 2003, to an all-time low in 2019, but crept back up beginning in 2020 with increased assassinations of community leaders.[4,27] Latin America has been characterized as a violent region, with explanations ranging from socioeconomic inequality including land inequality, political instability, structural violence, youth disenfranchisement, and institutional capacity.[28] But among Latin American countries with common histories and similar levels of socioeconomic inequality, Colombia stands out with one of the highest homicide rates.

Some studies on spatial distribution of homicides in Colombia have been conducted: Vallejo et al. 2018 studied urban vs rural homicides in Colombia from 1992-2015, Sandoval (2018) studied socioeconomic determinants of spatial patterns in homicide from 2000-2010, and Castilla and Salas (2008) created detailed maps and discussions of violent deaths over Colombia from 1992-2005, including both homicides and conflict-related deaths.[11,28,29] The report by Castilla and Salas contextualizes the spatiotemporal trends with historical and ecological information, but traces only crude homicide rates by municipality and department, without any estimation or spatial smoothing methods. Urdinola et al. (2017) applied Bayesian and small-area estimation methods to homicides in Colombia from 1990-2009. While both studies tracked the dynamics of the armed conflict in Colombia coinciding with the homicidal trends, the present study is one of the first to quantitatively track the armed conflict in parallel with homicide rates. Additionally, the present study extends past the 2016 peace process through 2019, providing additional information on the dynamics of violent death by including 3 years post- formal resolution to the conflict. Nevertheless, the analyses by Vallejo et al. provide important evidence on the blurry line between homicides and conflict-related deaths, and Urdinola et al additionally analyze the degree of under-registration of deaths in Colombia's official records at the municipality level.[29,30]

In urban areas of Colombia, the rise of narco-trafficking in the 1980's led to increased activity of urban drug cartels, associated with an urban homicide rate that peaked in 1992, and progressively decreased through that decade.[31] In contrast to other parts of the world where deaths due to criminal homicide outweigh those due to conflict, even in countries experiencing armed conflict, Vallejo et al. found that, coinciding with the dynamics of Colombia's armed conflict, there were more homicides in rural areas than in urban areas in each year from 1993-2014.[29] The urban/rural disparity is also reflected in victimization surveys, which recently estimated that 25% of Colombians living in urban Bogotá and nearly 66% of Colombians in the rural Amazonía-Orinoquía region were victims of the armed conflict.[32]

One reason for homicide rates to increase in a post-conflict period is simply that they are better reported in a time when there is theoretically more institutional stability/presence. Indeed, data collection face a number of challenges when armed conflict is present. Data on conflict-related incidents and deaths are almost always incomplete and under-reported, with non-random patterns of missingness.[33] Research on the topic has shown that armed conflict events are a more reliable indicator than armed conflict fatalities.[34,35] In this study we apply spatial and non-spatial smoothing models to homicide and armed conflict trends to trace the spatial patterns of violence in Colombia. We identify 'hot spots' or clusters of violence that change over time, which may reflect the influence of armed groups' expansion or seizure of land, strategic interest in extractable resources, and certain policies or state responses to conflict dynamics.[13,36]

In this study we describe the spatial trends of armed conflict and homicide in Colombia from 1990-2019. The study of violent death is important not just because of its gravity, but also because it is a specific and fairly well-measured outcome, comparable across different settings, and a relatively reliable indicator of overall violence.[19,37] Understanding how violence is distributed over space or time can shed light on the underlying determinants of violence, such as migration, organized crime, drug trafficking, and/or structural determinants like socioeconomic inequality, in addition to providing an ability to assess the effectiveness of interventions aimed at violence prevention.[38] These results may be helpful to inform policy and shape social development prioritization in Colombia.

METHODS

Colombia's internal political divisions consist of 32 departments, analogous to US states, which are further separated into a total of 1122 municipalities, which are like US counties. The capital, Bogotá, is an exception as both a department and a municipality. The study period includes all years from 1990 through 2019, which we broke down into 5-year bands for analyses.

Separate analyses were conducted for homicides and armed conflict. Homicide counts were abstracted from Colombia's vital statistics registries (managed by DANE).[39] In Colombia, every death resulting from suspected homicide is supposed to undergo an autopsy, with medical examiners listing causes and contributory causes on a formal death certificate.[40] While data quality and death notifications undoubtedly suffer in the context of acute armed conflict or mass casualty events, or belatedly reported casualties, DANE's death registry has been found to be fairly reliable.[30] Deaths due to homicides were identified using Colombia's Lista 105 death classification system, which has remained consistent over the study time period. We included as homicides both deaths due to assault, which correspond to ICD-10 (2016 version) codes X85-Y09 and ICD-9 codes E960-E969, as well as deaths due to legal intervention/operations of war, which correspond to ICD-10 codes Y35-Y36 and ICD-9 codes E970-E978 and E990-E999. Homicide counts were age-standardized for each municipality-year.

Annual population counts for each municipality were also taken from DANE population estimates based on the 2018 census, and geographic shapefiles were also provided by DANE.[41]

Armed conflict was measured in counts of conflict events and data were from Colombia's National Center for Historic Memory (Centro Nacional de Memoría Histórica, CNMH).[42] Conflict data were updated in June 2022 so that retroactively-reported conflict events through the present were included. Briefly, the CNMH categorizes conflict events into one of 11 categories, which were all summed together to create a total conflict event count for each municipality-year in this analysis. The categories were mutually exclusive; incidents of different categories that occurred simultaneously in the same area were categorized based on the primary act that was brought to the CNMH.[43] Each event could result in many fatalities, or in no fatalities. The conflict events include: military actions, selective assassinations, attacks on villages or population centers, terrorist attacks, attacks on infrastructure, massacres, kidnapping, forced disappearances, recruitment of children, sexual violence, and antipersonnel mines/unexploded munitions.

Statistical Analyses

A crude standardized mortality rate (SMR) was computed as the ratio of observed to expected counts of each homicide and conflict events. Expected counts were based on annual national totals of each, and population standardized for each municipality. Homicides were age-standardized but conflict events were not standardized by age. SMRs assume a constant homicide rate over each municipality-year, and that every resident of the municipality is at the same risk of homicide at any given time.

First, we constructed non-spatial Poisson-Lognormal smoothing models for each 5-year band of homicides. With i designating each municipality (i = 1, 2, …. 1122), we modeled the count of homicides y_i with a Poisson distribution around mean μ_i (Equation 1)

$$y_i \sim Poisson(\mu_i) \qquad (1)$$

Under the proportionality assumption, μ_i is equal to the product of E_i, the expected number of cases from the indirectly standardized SMRs , and θ_i, the relative risk of homicide in municipality i (Equation 2).[30,44]

$$\mu_i = E_i \times \theta_i \qquad (2)$$

Homicides and conflict events are both rare outcomes, so the variance in each exceeds the mean count predicted by the statistical models. To address the extra variation, we included a random effect for each area, allowing the area's risk to vary on a latent variable. Therefore the non-spatial model decomposed the following model.[44–46]

$$\log(\mu_i) = \log(E_i) + \alpha + u_i \qquad (3)$$

Where α is the intercept or overall risk, and u_i represents the non-spatially dependent random effects, which we specified as independent and identically distributed (IID). This model does not take into account the distribution of homicide in neighboring municipalities, but smooths estimates so that outliers are shifted towards the center of the data distribution.

Then we applied an updated version of the spatial Besag-York-Mollié (BYM) model that allows for better interpretation of spatial effects, called BYM2, which is commonly used in spatial epidemiology to predict count outcomes.[47] BYM2 models incorporate IID random effects and also spatial random effects that incorporate the spatial structure of municipalities (Equation 4). The BYM2 model therefore includes both normally distributed error terms and a spatial component which is estimated from the weighted mean of homicide counts in each municipality's neighboring areas, defined as municipalities sharing a common border. Because of this, Colombia's two island municipalities (San Andrés y Providencia) were excluded from the spatial analyses.

$$\log(\mu_i) = \log(E_i) + \alpha + u_i + \delta_i \qquad (4)$$

Where u_i and δ_i are the unstructured and structured main spatial effects, which respectively account for non-spatially dependent and spatially dependent-variance in μ_i. The spatially structured random effects were assigned intrinsically conditional autoregressive prior (ICAR) distributions, and vague or non-informative priors were specified for the hyper-parameters that describe the variance of the prior distributions. Posterior distributions for both spatial and non-spatial smoothing models were estimated with integrated nested Laplace approximations.[44]

Finally, we applied cluster detection methods to identify areas with likely clusters of homicides. Using the SaTScan method of drawing centroids drawn from the center of each municipality, we estimated Moran's I test of global clustering and Geary's C test of local clustering to identify clusters, or homicide 'hot spots'. We computed both Moran's I and Geary's C statistics using both binary weights and standardized weights.

All analyses of homicides were repeated for armed conflict events.

Analyses were conducted in R using the INLA package.

RESULTS AND DISCUSSION

From 1990 – 2019, homicide and conflict maps generally coincided with the dynamics of Colombia's armed conflict. **Figure 1.1** shows maps of the observed homicide rate per 100,000 by municipality over time, and **Figure 1.2** shows the observed counts of armed conflict incidents by municipality over time. **Figures 1.3** and **1.4** depict maps of the non-spatially smoothed estimates of homicides and armed conflict, respectively. The spatially-smoothed estimates for homicide and armed conflict are shown in **Figures 1.5** and **1.6**. When comparing figures of non-spatially smoothed and spatially-smoothed estimates, the maps appear quite similar. The crude SMR and model estimates for select municipalities are shown in **Table 1.1**. Figures comparing SMRs and model-estimated RRs are shown in **Appendix 1**.

Areas of most likely ($p<0.05$) clusters of homicides are highlighted in **Figure 1.7**, and areas of most likely armed conflict clusters are shown in **Figure 1.8**, which also depicts the 'priority' PDET municipalities named by the government for targeted investment due to historic presence of armed conflict. While areas with disproportionately high homicide levels remained consistent over the study period (**Figure 1.7**), we observed an abrupt shift in most likely clusters of armed conflict. Armed conflict clustered in the northern part of the country around the Antioquia department from 1990-2004, and then in 2005-2009 the armed conflict clusters shifted to the far south of the country, subsequently concentrating in the southwest corner of the country in 2015-2019 (**Figure 1.8**). In contrast, homicide clusters were generally persistent over time in the northwest of the country, including the Urabá, Northwest Antioquia, and Chocó regions through 2004, then shift south to span Chocó and Valle del Cauca departments from 2005-2019 (**Figure 1.7**). In all periods studied, we observed a persistent spike in homicide risk over the Darién or Urabá region in Colombia's north, which is an area known for its violence and criminal trafficking activities.[48] Both homicide and armed conflict clusters generally align with municipalities the Colombian government designated in 2018 for priority investment under PDET because they were historically affected by armed conflict, or exhibit high levels of 'multidimensional poverty' (shown in red outlines in **Figure 1.8**).[49]

Coefficients from both spatial and non-spatial smoothing models are shown in Table **1.2**. In almost all time periods for both homicides and armed conflict, the total residual variance (σ^2) was greater in the non-spatial model than the spatial model, indicating that at least some of the variance was attributable to spatial effects. Taking a closer look at the model coefficients for homicides, we see that $\phi = 0.63$ (95% credible interval [CI] 0.52, 0.74) for the time period 1990-1994, indicating that 63% of the inter-municipal variance in homicides was attributable to spatial autocorrelation in that time period. The posterior median of ϕ for homicides is similar in 1995-1999, and is then incrementally smaller in each time period, reaching ϕ =0.46 (95% CI 0.34, 0.58) in 2015-2019. These values suggest that homicides became more spatially diffuse over time.

Compared to homicides, we observed that slightly less of the variance in armed conflict was attributable to spatial effects, especially in earlier years ($\phi = 0.51$; 95% CI 0.40, 0.63 in 1990-1994). When comparing violence between municipalities, more of the variance in armed conflict is explained by spatial autocorrelation than the variance in homicides, for all time periods studied except 2015-2019. In this most recent time period, both homicides and armed conflict shared similar proportions of spatial dependence ($\phi = 0.48$; 95% CI 0.35, 0.60 for armed conflict and $\phi = 0.46$, 95% CI 0.34, 0.58 for homicides) (**Table 1.2**). In other words, spatial variation accounted for about half the total variance of municipal rates of violence around the national average, for homicides a bit more so than for armed conflict.

Cluster statistics for Moran's I and Geary's C indicating the degrees of spatial clustering of homicides and armed conflict are shown in **Table 1.3**. Moran's I ranges from [-1, 1], with positive values indicating positive spatial autocorrelation, or clustering. As shown in **Table 1.3**, I-statistic values constructed from binary weights range from 0.43 (in 1990-1994) to 0.52 (in 2005-2009) for homicides , indicating statistically significant clustering of municipalities with higher homicide rates in all years. Moran's I statistic values ranged from 0.48 (in 2015-2019) to 0.61 (in 1995-1999) for conflict events, indicating moderately stronger, statistically significant clustering of municipalities with high levels of conflict. Geary's C statistic, which measures more local clustering, ranges from [0, 2], where values less than 1 indicate positive spatial correlation. C-statistic estimates from binary weights for homicides ranged from 0.54 in 1990-1994 to 0.80 in 2010-2014, indicating positive clustering in all years with weaker magnitude of clustering in more recent years. Similarly, Geary's C estimates for armed conflict ranged from 0.55 in 1995-1999 and in 2015-2019 to 0.66 in 2005-2009, also indicating positive spatial autocorrelation, with no clear time trend.

The counts of homicides, armed conflict events, SMRs and estimated RRs for selected municipalities shown in **Table 1.1** help explain some of these apparently conflicting results. In 1990-1994, Colombia's armed conflict was very active in the Urabá region (e.g., Apartadó municipality), the adjacent Darién forest (e.g., Riosucio municipality) and surrounding municipalities in northern Antioquia (e.g., Tarazá municipality). Large cities like Cali, Bogotá, and Buenaventura were less likely to experience armed conflict events 1990-1994 compared to other areas in that time period. Both Cali and Buenaventura observed higher than average homicides but fewer than average armed conflict events in all years. Bogotá, the capital, observed fewer than average homicides and fewer than average armed conflict related incidents in all time periods studied. In contrast, Colombia's capital city Bogotá, as well as rural areas Apartadó and Tarazá showed higher than average armed conflict and homicides in all years.

Some of these municipalities were selected because there was known lack of state presence in some years due to the armed conflict. For example, San Vicente del Caguán is a rural municipality in southern Colombia that the then-President declared a de-militarized zone from 1998-2002, and removed all state actors as a gesture of good will towards peace negotiations.[12] While our time bands divide this period, we can see that this municipality still observed higher than average homicides and armed conflict for years except from 1990-1994. On the other hand, Riosucio in the far north of the country is the land bridge that connects Colombia, and the rest of South America, to Panama, and straddles the Caribbean Sea and Pacific Ocean. This area is densely forested, and while there is no road connecting Panama to Colombia (an absence known as the Darién Gap), much illegal trafficking of humans, drugs, and other goods, as well as coca cultivation is known to occur in this region.[22] In our analyses, Riosucio observed more conflict events than average, but many fewer homicides than average. This may be due to measurement issues or poor data collection in the area due to low institutional presence. The Tibú municipality, in Norte de Santander, is located in the northeast of Colombia, on the border with Venezuela. As shown in **Table 1.1**, the municipality observed an elevated risk ratio for both homicides and armed conflict. The RRs for violence in Tibú are correlated, but appear to diverge in more recent years, with BYM2 RR=2.03 for homicides and RR=8.45 for armed conflict in 2010-2014, and RR=4.75 for homicides and RR=19.59 for armed conflict in 2015-2019. This municipality has historically fostered a FARC presence, and is well-supplied with firearms from Venezuela.[50] The trend of increasing violence in Tibú relative to the rest of Colombia coincides temporally with the economic de-stabilization of Venezuela.[50,51]

Our findings support the hypothesis that violent deaths tend to cluster spatially. The patterns shown in **Figures 1.1-1.8** indicate that homicides and armed conflict related violence tend to occur in the same areas. This supports the idea that many homicides may be linked to the armed conflict, either directly through extrajudicial killings or civilian assassinations, or indirectly through killings linked to organized crime, drug trafficking, or other illegal activities that tend to occur in areas where armed groups are or were active, and low institutional capacity.[12] Main guerrilla groups of the armed conflict, FARC and ELN, are fighting for communist/socialist platforms, but are also international groups involved in narco-trafficking and other illegal activities.[52] In other words, there is a blurred line between homicide and armed conflict. Furthermore, state-supported paramilitary groups were responsible for a disproportionate number of assassinations/homicides in Colombia's armed conflict, but on the other hand they also put a stop to illegal activities.[53]

The distinction between homicides linked to armed groups vs those due to individuals is not clear, but prior research has shown the relative proportion of each in Colombia has shifted over time. In the 1990's the mayor of Cali, one of Colombia's most violent cities, was a Harvard-trained violence epidemiologist and led several initiatives to understand the causes and distributions of violence in his city. He found that the majority of violence was due to interpersonal conflicts, rather than armed groups, and observed that socioeconomic or structural drivers of violence were more salient causes of violence.[54] He then implemented some policies based on his findings and was able to reduce violence in his city. Years later however, the dynamics appear to have switched with armed groups accounting for over 2/3 of homicides in Colombia today. The presence and power of armed groups are also linked to socioeconomic issues like land inequality, disenfranchisement, and unemployment, but require more upstream approaches of violence prevention to address.[36]

Another important trend that coincided with peaks in violent death in Colombia is the role of US involvement. A lot of Colombia's problems stem from acute socioeconomic inequality, particularly land inequality. Many of these inequities are historically entrenched, but were introduced or exacerbated by US policies. In the 1980s the US and World Bank strongly campaigned for neoliberal structural adjustment policies, which privatized utilities and exacerbated inequalities.(CITE) In the Urabá region, US companies enjoyed a largely unregulated presence for decades, in particular United Fruit which later became Chiquita Brands. Chiquita bananas supported the FARC with monthly payments in the early 1990s when the FARC fought against another rebel group, and from 1995-2004 Chiquita financed paramilitary violence in Urabá with payments totaling $1.7 million.[55] Moreover, since the early 2000's, the US has provided over $10 billion in mostly military aid to the Colombian government under Plan Colombia.[56] The US involvement with Plan Colombia, ostensibly to conduct a war on drugs, contributed to the privatization of violence and other conditions that exacerbated armed conflict in Colombia.

This study is subject to limitations. Data on conflict-related incidents and deaths are almost always incomplete and under-reported. In this study, we did not attempt to count conflict-related deaths, but rather a more sensitive measure of conflict-related incidents, which researchers consider a better metric of armed conflict-related violence.[34,35] Conflict data were compiled, as directed by law, by the Center for Historic Memory in Colombia, which has gone through careful data processing to remove duplicates; however, there are many reasons why armed conflict-related events might be missing from this data, even if they did occur. This study analyzed patterns of spatial variation in violence at the municipality-level. We could not assess anything about within-municipality variation of violence—future research should analyze the spatial distribution of violent death at a more granular level of space, and by motivation or responsible party. Questions also remain about the distributions of injury due to violence, self-directed violence, and gender-based violence.

Conclusion

This research analyzed violent death trends in Colombia, a country in a unique position between entrenched armed conflict and elusive peace, with one of the highest homicide rates in the world. The results show high degrees of spatial clustering at the municipality level of both homicide deaths and armed conflict events. Such strong spatial clustering lends support to the efforts of the Colombian government with the PDET initiative, that designated areas at the municipality level for prioritized investment. Many of these initiatives for improved state infrastructure and investment were promised by the government under the 2016 peace accords but have yet to be implemented. The historic election of Gustavo Petro in June 2022, the first leftist president of Colombia ever and himself a former rebel group member, has given Colombians hope that the promised social investments and economic reforms will materialize, but there is much work to be done to address entrenched structural inequality.[57] Nevertheless, the epidemiological study of violent death has led to finely-tuned, impactful policy and reductions in urban violence in Colombia before. While the dynamics of violent death and armed groups have changed since the 1990's, this updated assessment of spatial trends in violence for this critical time in Colombia may help guide updated public health approaches to violence prevention.

Table 1.1. Estimates from Select Municipalities (*continues to next page)*

Municipality	Department	Time Period	Avg Annual Pop.	*Homicide*				*Armed Conflict*			
				N Obs	SMR	RR (Lognormal)	RR (BYM2)	N Obs	SMR	RR (Lognormal)	RR (BYM2)
Apartadó	Antioquia	1990-1994	62,306	1339	5.70	5.69	5.69	929	12.32	12.30	12.30
		1995-1999	73,776	1260	5.92	5.91	5.91	1668	11.87	11.86	11.86
		2000-2004	85,139	583	2.29	2.28	2.28	773	2.99	2.99	2.99
		2005-2009	95,985	294	1.64	1.64	1.64	266	2.81	2.81	2.81
		2010-2014	106,801	220	1.33	1.32	1.33	197	3.81	3.80	3.80
		2015-2019	118,502	233	1.66	1.66	1.66	40	2.96	2.92	2.93
Tarazá	Antioquia	1990-1994	17,321	284	4.98	4.95	4.93	201	9.59	9.54	9.54
		1995-1999	19,207	206	4.20	4.17	4.15	333	9.12	9.09	9.10
		2000-2004	21,089	219	3.65	3.63	3.61	403	6.29	6.28	6.28
		2005-2009	22,828	336	8.20	8.14	8.13	337	14.92	14.87	14.86
		2010-2014	24,566	162	4.38	4.33	4.34	219	18.36	18.28	18.23
		2015-2019	26,484	254	8.76	8.67	8.64	54	17.84	17.48	17.30
Bogotá	Bogotá	1990-1994	4,966,150	15935	0.85	0.85	0.85	489	0.08	0.08	0.08
		1995-1999	5,762,059	9541	0.57	0.57	0.57	563	0.05	0.05	0.05
		2000-2004	6,407,838	9496	0.48	0.48	0.48	835	0.04	0.04	0.04
		2005-2009	6,877,747	7365	0.56	0.56	0.56	493	0.07	0.07	0.07
		2010-2014	7,185,380	7066	0.62	0.62	0.62	164	0.05	0.05	0.05
		2015-2019	7,383,414	6228	0.70	0.70	0.70	40	0.05	0.05	0.05
San Vicente del Caguán	Caquetá	1990-1994	32,644	99	0.92	0.91	0.91	104	2.63	2.62	2.62
		1995-1999	37,180	220	2.22	2.21	2.19	259	3.66	3.65	3.65
		2000-2004	41,084	317	2.73	2.72	2.72	470	3.77	3.76	3.76
		2005-2009	44,268	327	4.25	4.22	4.21	444	10.14	10.11	10.12
		2010-2014	47,499	255	3.64	3.62	3.58	267	11.58	11.54	11.55
		2015-2019	50,340	197	3.52	3.49	3.43	49	8.50	8.35	8.39
Riosucio	Chocó	1990-1994	22,734	18	0.25	0.26	0.31	61	2.22	2.20	2.19
		1995-1999	24,159	26	0.42	0.43	0.48	621	13.56	13.53	13.53
		2000-2004	23,472	21	0.33	0.35	0.38	236	3.34	3.33	3.33
		2005-2009	31,937	27	0.49	0.50	0.54	76	2.46	2.44	2.46
		2010-2014	41,892	23	0.36	0.37	0.41	76	3.77	3.74	3.77
		2015-2019	51,393	40	0.65	0.65	0.69	55	9.40	9.25	9.35

(*cont. next page*)

Municipality	Department	Time Period	Avg Annual Pop.	*Homicide*				*Armed Conflict*			
				N Obs	SMR	RR (Lognormal)	RR (BYM2)	N Obs	SMR	RR (Lognormal)	RR (BYM2)
Cali	Valle del Cauca	1990-1994	1,819,188	8731	1.27	1.27	1.27	327	0.15	0.15	0.15
		1995-1999	1,944,653	10214	1.79	1.79	1.79	408	0.11	0.11	0.11
		2000-2004	2,038,529	11132	1.79	1.79	1.79	811	0.13	0.13	0.13
		2005-2009	2,112,335	8626	2.22	2.22	2.22	550	0.26	0.26	0.26
		2010-2014	2,164,027	9674	3.01	3.00	3.00	241	0.23	0.23	0.23
		2015-2019	2,211,448	6746	2.77	2.77	2.77	43	0.17	0.17	0.17
Buenaventura	Valle del Cauca	1990-1994	252,987	1339	1.50	1.50	1.50	240	0.78	0.78	0.78
		1995-1999	268,492	1161	1.57	1.57	1.57	342	0.67	0.67	0.67
		2000-2004	280,950	1638	2.02	2.02	2.02	998	1.17	1.17	1.17
		2005-2009	291,211	1399	2.73	2.72	2.72	963	3.33	3.33	3.33
		2010-2014	298,676	732	1.69	1.69	1.69	466	3.21	3.20	3.21
		2015-2019	305,800	431	1.31	1.31	1.31	101	2.88	2.87	2.87
Tibú	Norte de Santander	1990-1994	37,121	183	1.54	1.53	1.53	184	4.10	4.08	4.09
		1995-1999	40,095	286	2.78	2.77	2.76	549	7.22	7.21	7.21
		2000-2004	42,193	826	7.00	6.98	6.98	1808	14.11	14.10	14.10
		2005-2009	45,202	233	3.03	3.01	3.00	274	6.13	6.11	6.10
		2010-2014	48,255	146	2.06	2.04	2.03	199	8.49	8.46	8.45
		2015-2019	52,469	293	4.80	4.77	4.75	118	19.78	19.59	19.59

SMR = Standardized mortality ratio; RR = Risk ratio

Table 1.2. Posterior medians and 95% intervals, total variance of the random effects, and percent of variation attributable to the spatial random effect

	1990-1994		**1995-1999**		**2000-2004**		**2005-2009**		**2010-2014**		**2015-2019**	
	Post. Med	95% CI	Post. Med	95% CI	Post. Med	95% CI	Post. Med	95% CI	Post. Med	95% CI	Post. Med	95% CI
Homicides												
BYM2 model												
α	-0.70	(-0.74, -0.65)	-0.45	(-0.49, -0.41)	-0.18	(-0.22, -0.13)	-0.27	(-0.31, -0.22)	-0.53	(-0.57, -0.48)	-0.40	(-0.45, -0.35)
σ_b^2	1.04	(0.91, 1.19)	1.01	(0.88, 1.16)	0.94	(0.83, 1.08)	0.80	(0.71, 0.92)	0.79	(0.69, 0.90)	0.76	(0.67, 0.86)
ϕ	0.63	(0.52, 0.74)	0.64	(0.53, 0.75)	0.53	(0.41, 0.65)	0.52	(0.40, 0.63)	0.52	(0.41, 0.64)	0.46	(0.34, 0.58)
Lognormal model												
α	-0.68	(-0.76, -0.61)	-0.46	(-0.53, -0.39)	-0.18	(-0.24, -0.12)	-0.27	(-0.33, -0.21)	-0.52	(-0.58, -0.45)	-0.38	(-0.44, -0.32)
σ_ϵ^2	1.27	(1.15, 1.41)	1.11	(1.01, 1.22)	0.99	(0.91, 1.09)	0.90	(0.82, 1.00)	0.97	(0.88, 1.08)	0.87	(0.79, 0.97)
Armed Conflict												
BYM2 model												
α	-0.63	(-0.70, -0.56)	-0.53	(-0.59, -0.46)	-0.21	(-0.27, -0.15)	-0.44	(-0.51, -0.37)	-1.07	(-1.17, -0.97)	-0.88	(-1.01, -0.77)
σ_b^2	2.12	(1.88, 2.43)	2.22	(1.96, 2.50)	1.79	(1.59, 2.00)	2.00	(1.79, 2.27)	2.94	(2.63, 3.45)	2.86	(2.44, 3.33)
ϕ	0.51	(0.40, 0.63)	0.55	(0.44, 0.66)	0.46	(0.35, 0.57)	0.49	(0.38, 0.59)	0.49	(0.37, 0.60)	0.48	(0.35, 0.60)
Lognormal model												
α	-0.65	(-0.75, -0.56)	-0.54	(-0.64, -0.45)	-0.21	(-0.29, -0.13)	-0.41	(-0.50, -0.32)	-1.02	(-1.15, -0.89)	-0.80	(-0.94, -0.66)
σ_ϵ^2	2.22	(2.00, 2.44)	2.33	(2.13, 2.56)	1.75	(1.61, 1.92)	2.08	(1.89, 2.33)	3.33	(3.03, 3.70)	2.86	(2.50, 3.23)

Note: α = Intercept; σ_b^2 = Total variance of random effects (BYM2); ϕ = Percent variation attributable to spatial random effects (BYM2); σ_ϵ^2 = Total variance of random effects (Lognormal); 95% CI = 95% credible interval

Table 1.3. Moran's I & Geary's C Statistics for Clustering

	Moran's I				**Geary's C**			
	Binary weights		Standardized weights		Binary weights		Standardized weights	
	I statistic	P-value	I statistic	P-value	C statistic	P-value	C statistic	P-value
Homicides								
1990-1994	0.43	<0.001	0.44	<0.001	0.54	<0.001	0.57	<0.001
1995-1999	0.45	<0.001	0.46	<0.001	0.69	<0.001	0.64	<0.001
2000-2004	0.49	<0.001	0.48	<0.001	0.77	<0.001	0.68	<0.001
2005-2009	0.52	<0.001	0.49	<0.001	0.78	<0.001	0.66	<0.001
2010-2014	0.45	<0.001	0.43	<0.001	0.80	0.006	0.71	<0.001
2015-2019	0.44	<0.001	0.42	<0.001	0.73	<0.001	0.68	<0.001
Armed Conflict								
1990-1994	0.59	<0.001	0.60	<0.001	0.58	<0.001	0.51	<0.001
1995-1999	0.61	<0.001	0.61	<0.001	0.55	<0.001	0.50	<0.001
2000-2004	0.51	<0.001	0.53	<0.001	0.63	<0.001	0.56	<0.001
2005-2009	0.52	<0.001	0.51	<0.001	0.66	<0.001	0.58	<0.001
2010-2014	0.55	<0.001	0.55	<0.001	0.60	<0.001	0.53	<0.001
2015-2019	0.48	<0.001	0.51	<0.001	0.55	<0.001	0.53	<0.001

FIGURES—AIM 1

Figure 1.1. Observed Homicide Rates per 100,000 Population in 5-year bands, 1990-2019

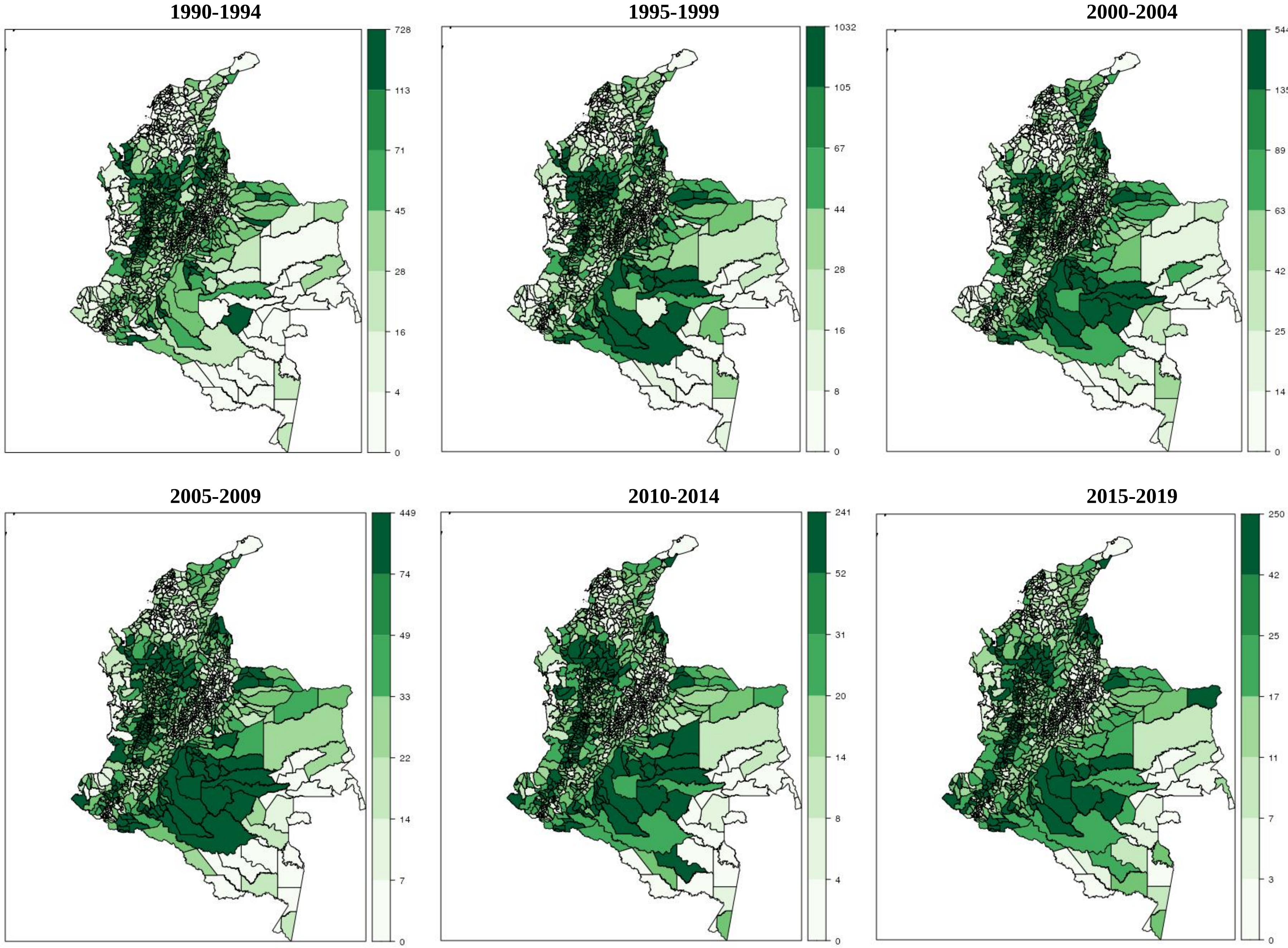


Figure 1.2. Observed Counts of Armed Conflict-Related Incidents in 5-year bands, 1990-2019

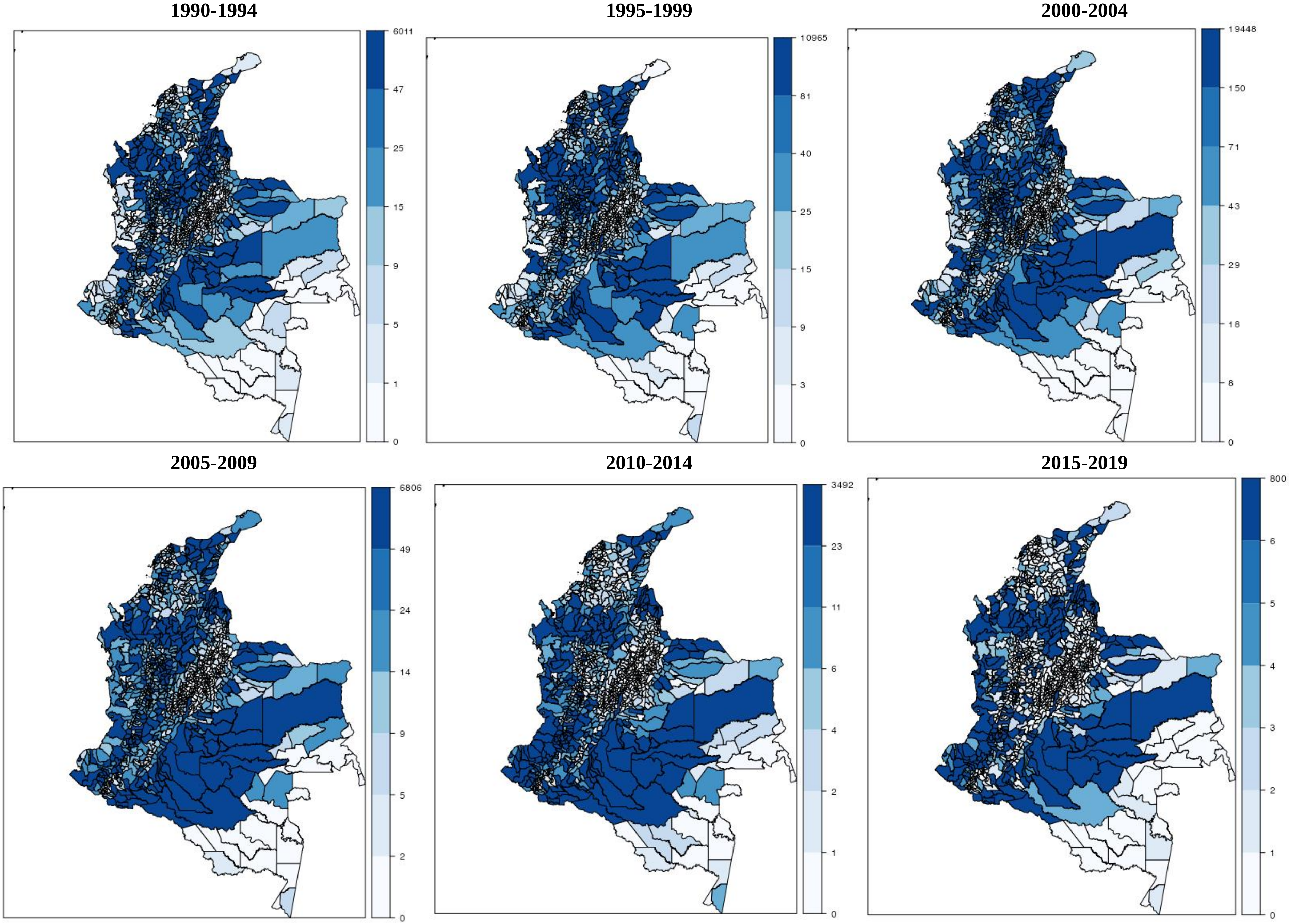


Figure 1.3. Poisson-Lognormal Estimates of RR by Municipality—Homicides

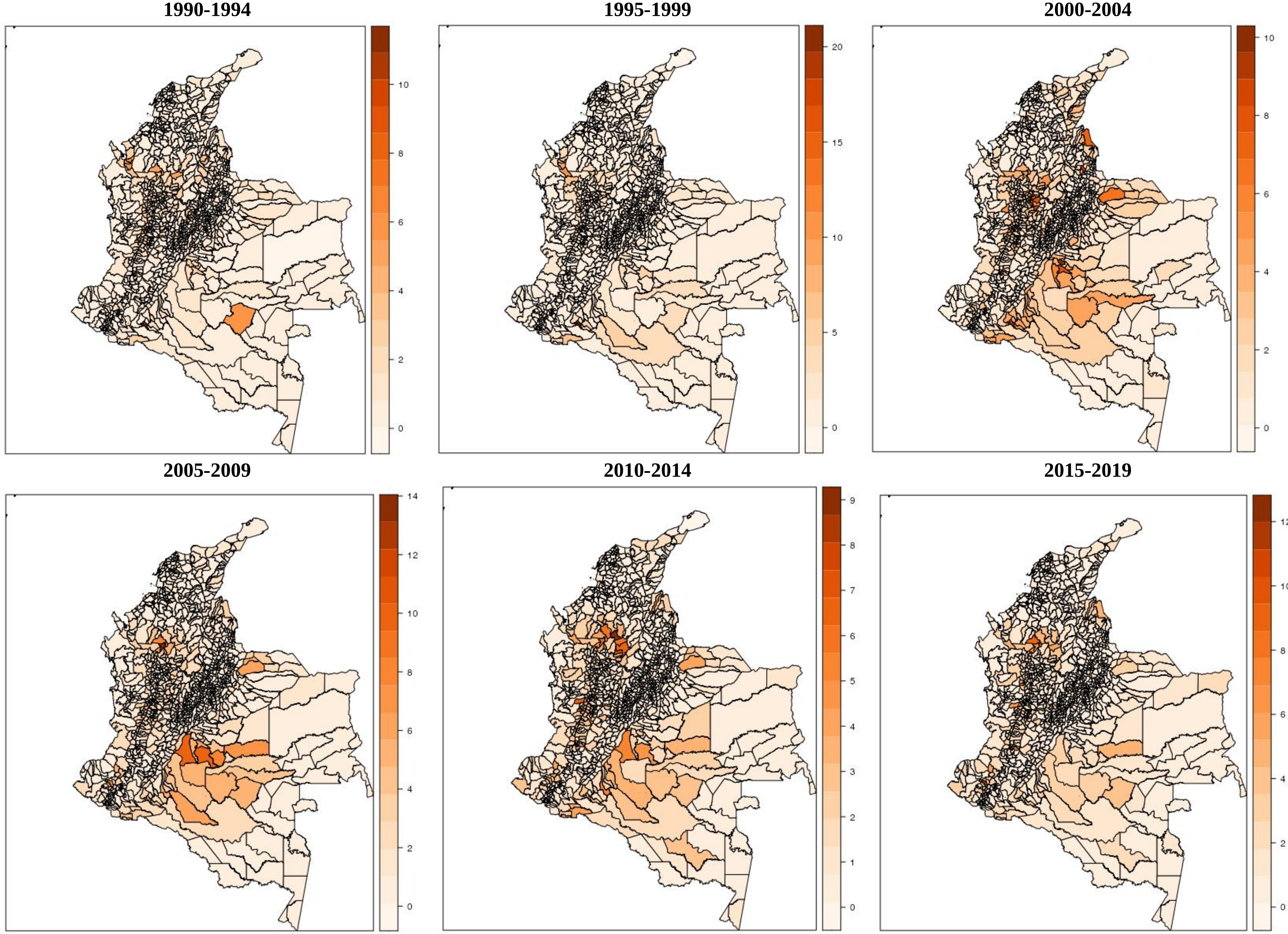


Figure 1.4. Poisson-Lognormal Estimates of RR by Municipality—Armed Conflict

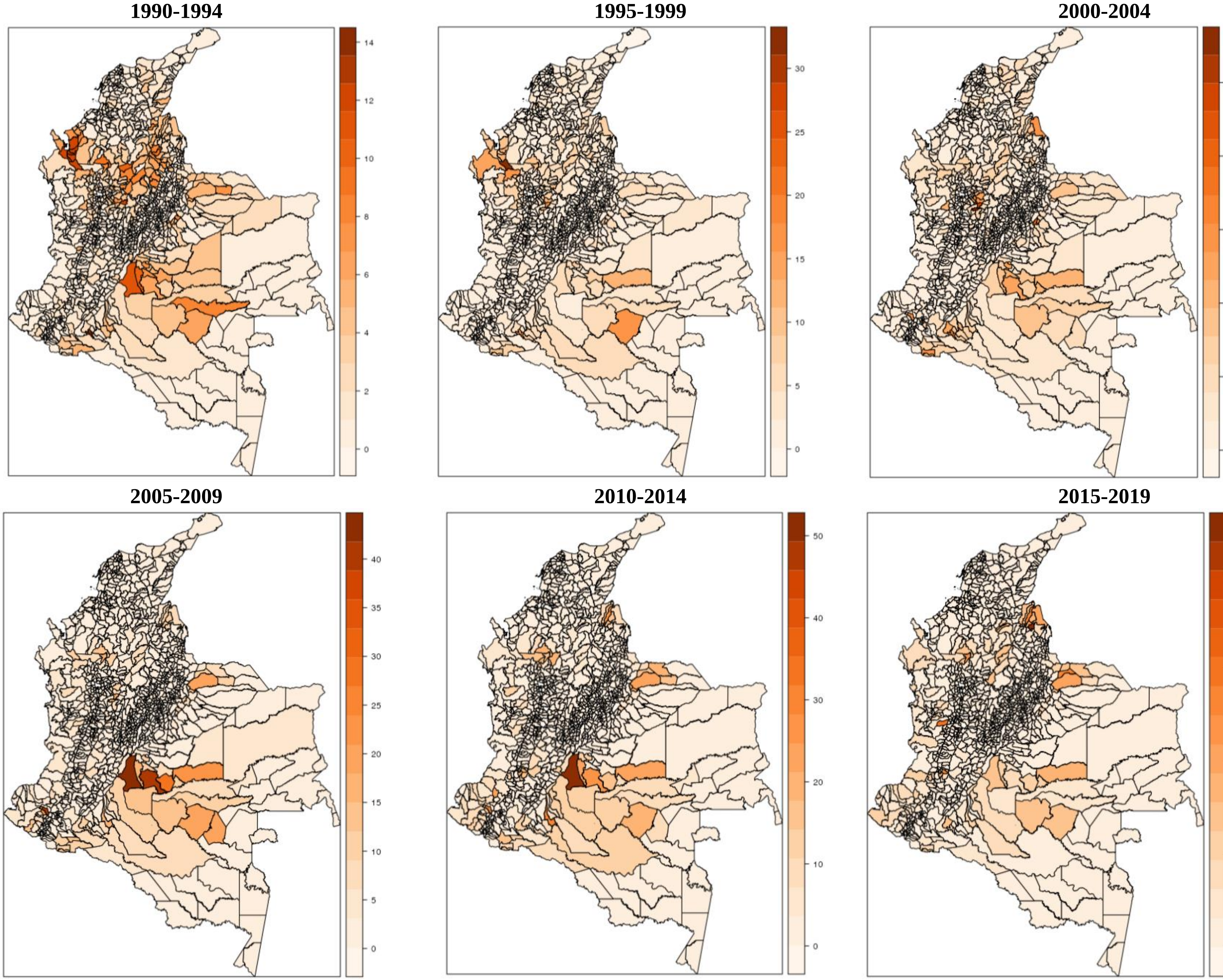


Figure 1.5. Risk Ratios Estimated by BYM2—Homicides

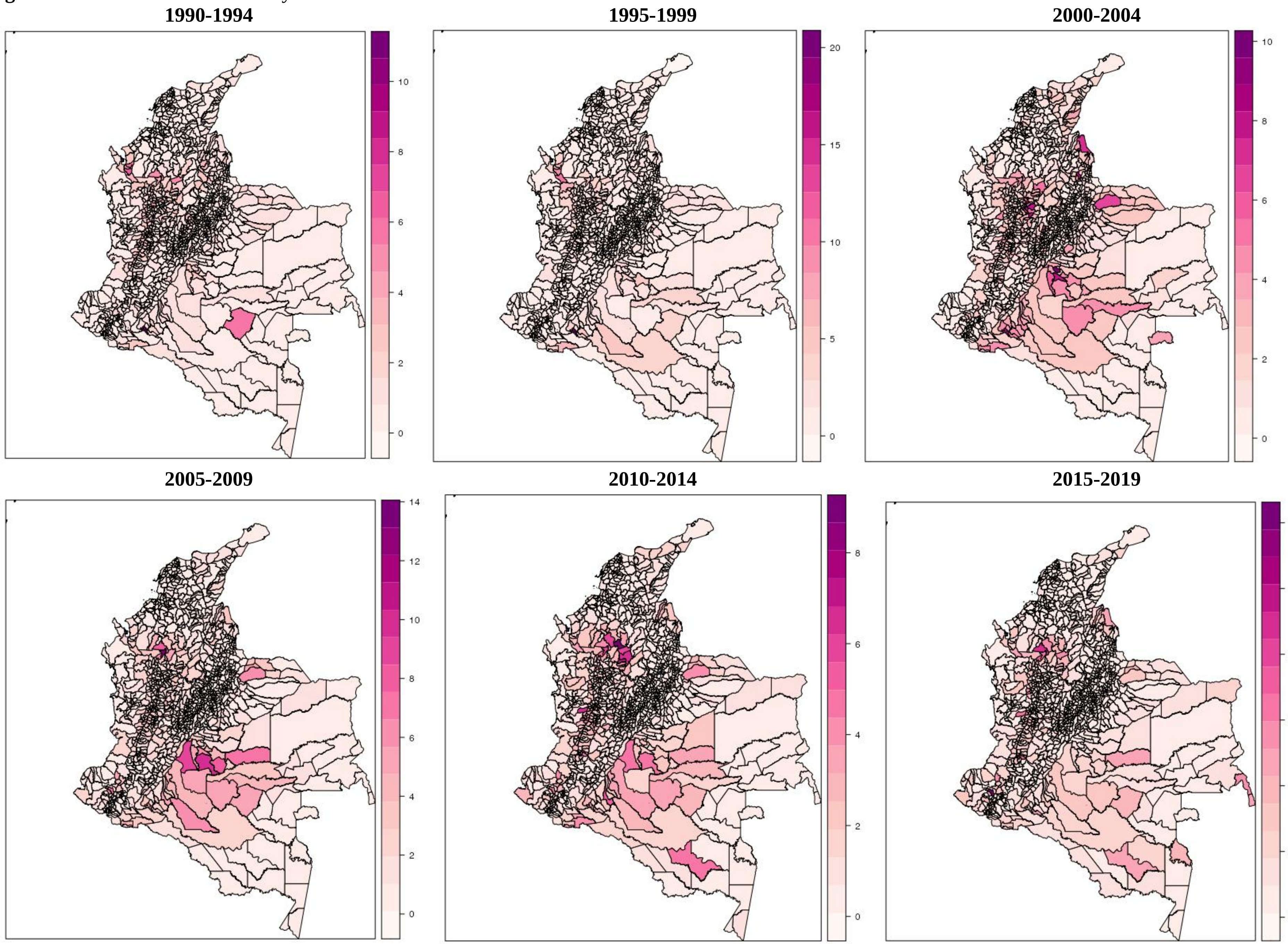


Figure 1.6. Risk Ratios Estimated by BYM2—Armed Conflict

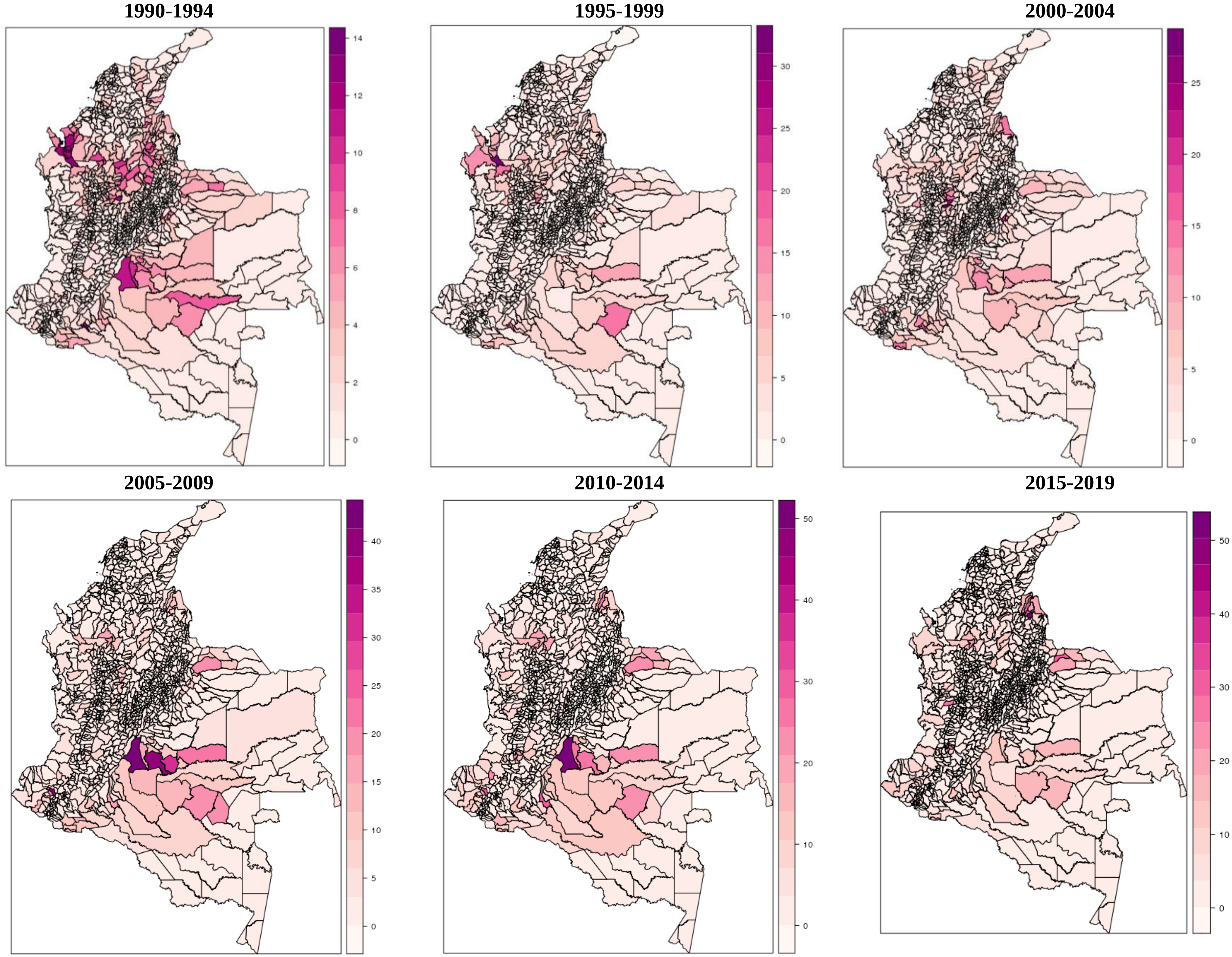


Figure 1.7. Most Likely Homicide Clusters

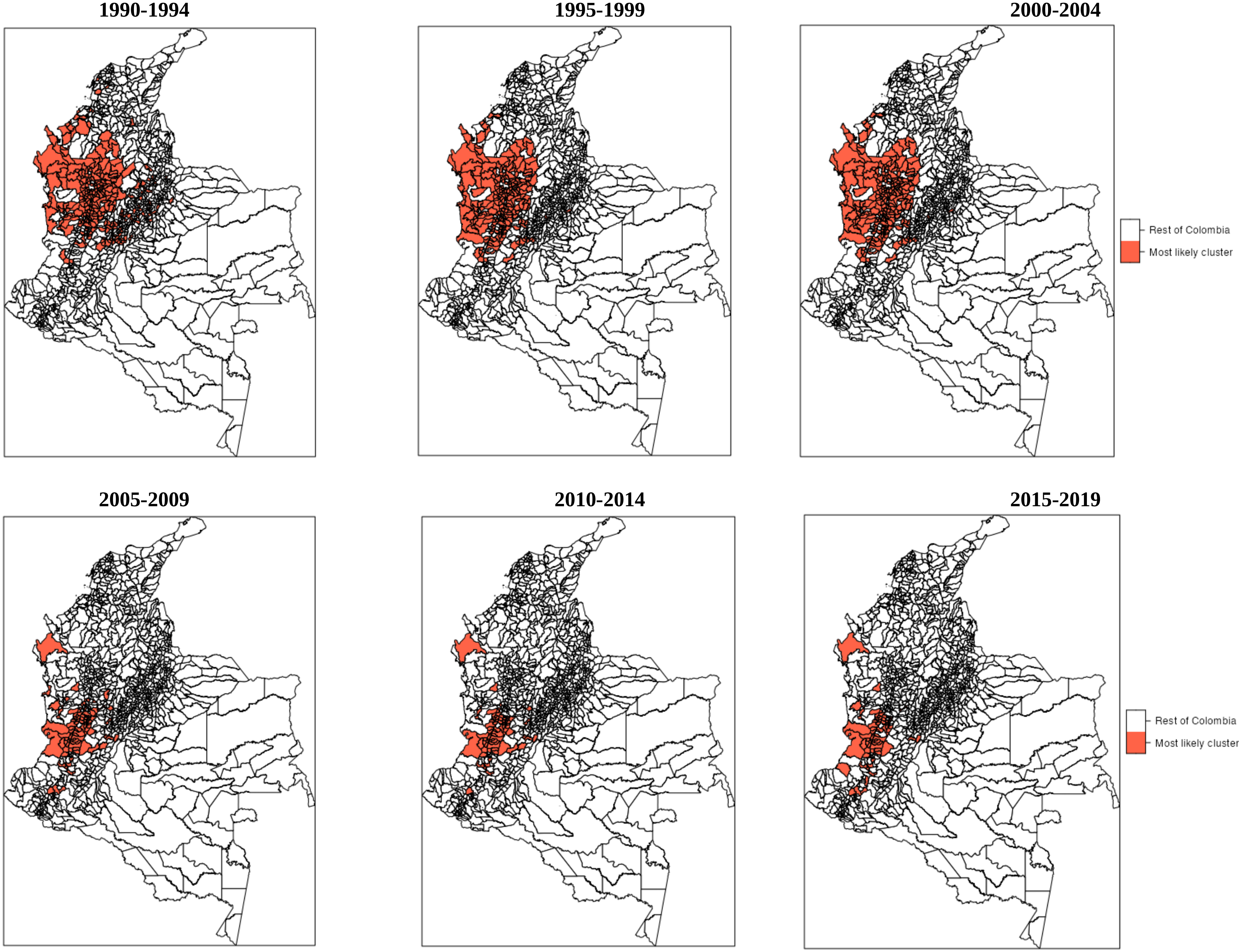
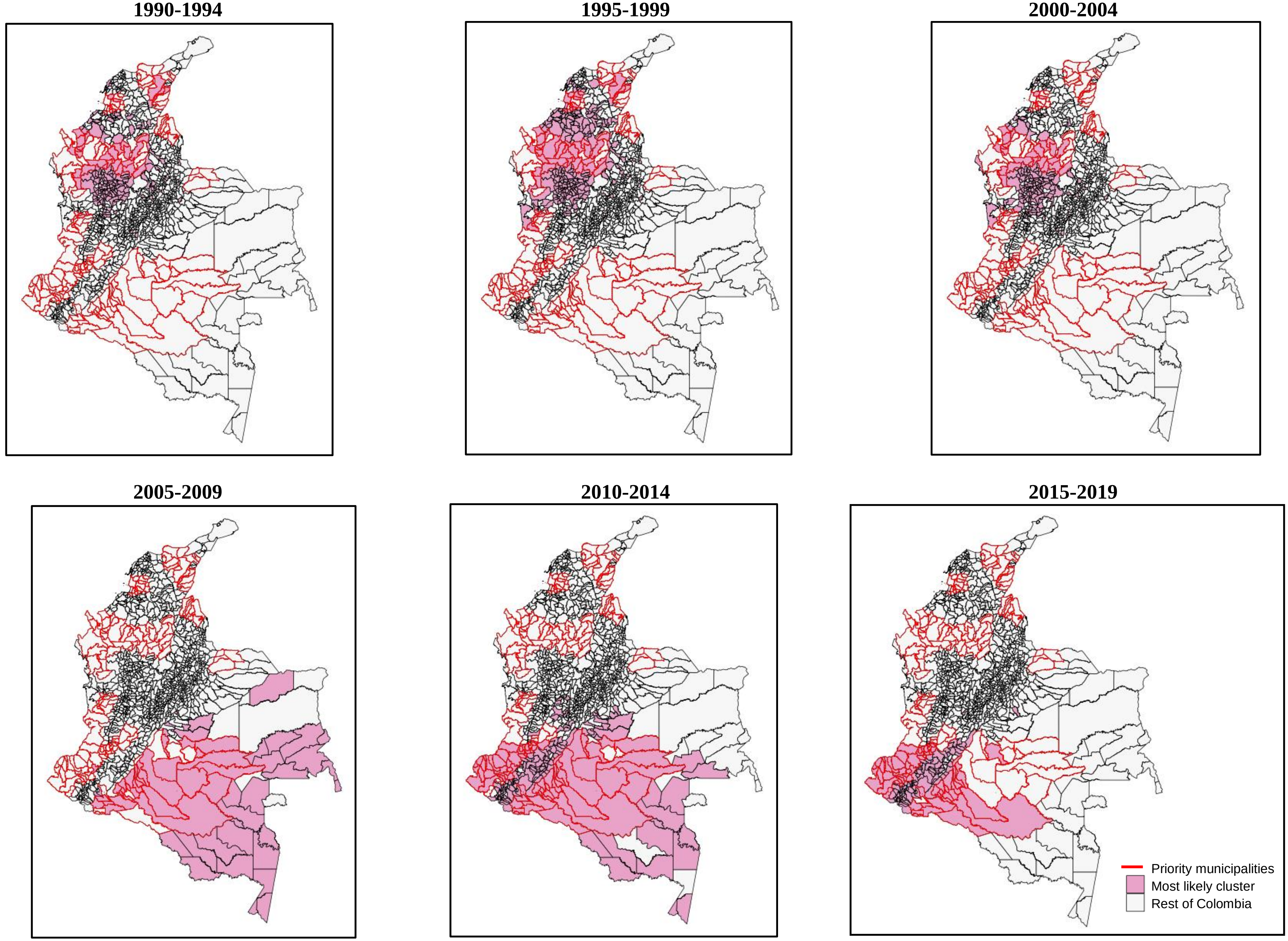


Figure 1.8. Most Likely Armed Conflict Clusters and Priority Municipalities



REFERENCES—AIM 1

1. Gordon S, Baker A, Duten A, Garner P. Study exploring the evidence relating Health and Conflict interventions and outcomes Commissioned by the UK Cross Government. 2010.
2. Schutte S, Weidmann NB. Diffusion patterns of violence in civil wars. *Polit Geogr*. 2011;30(3):143-152. doi:10.1016/j.polgeo.2011.03.005
3. Reza A, Mercy JA, Krug E. Epidemiology of violent deaths in the world. *Inj Prev*. 2001;7:104-111. doi:10.1136/ip.7.2.104
4. United Nations Office on Drugs and Crime. *Global Study on Homicide: Homicide Trends, Patterns and Criminal Justice Response*.; 2019.
5. Papachristos A V., Bastomski S. Connected in crime: The enduring effect of neighborhood networks on the spatial patterning of violence. *Am J Sociol*. 2018;124(2):517-568. doi:10.1086/699217
6. Walker BB, Schuurman N, Hameed SM. A GIS-based spatiotemporal analysis of violent trauma hotspots in Vancouver, Canada: identification, contextualisation and intervention. *BMJ Open*. 2014;4:3642. doi:10.1136/bmjopen-2013
7. Zeoli AM, Grady S, Pizarro JM, Melde C. Modeling the Movement of Homicide by Type to Inform Public Health Prevention Efforts. *Am J Public Heal Zeoli al | Peer Rev | Gun Violence Public Heal*. 2015;105(10):2035. doi:10.2105/AJPH
8. Carcach C. A spatio-temporal model of homicide in El Salvador. *Crime Sci*. 2015;4:20. doi:10.1186/s40163-015-0033-6
9. Lozano Ospino JE, Vega Maldonado MA, Tinjacá Uriza K. *Boletín Estadístico de Eventos de Violencia Durante El Conflicto Armado Interno N.3 Nacional*.; 2022.
10. Franco S, Mercedes Suarez C, Naranjo CB, Carolina Báez L, Rozo P. The effects of the armed conflict on the life and health in Colombia Os efeitos do conflito armado sobre a vida e a saúde na Colômbia. *Cienc e Saude Coletiva*. 2006;11(2):349-361.
11. Castilla CE, Salazar LGS. *Dinámica Espacial de Las Muertes Violentas En Colombia : 1990-2005*. Bogotá: Vicepresidencia de la República; 2008.
12. Salas Salazar LG. Lógicas territoriales y relaciones de poder en el espacio de los actores armados: un aporte desde la geografía política al estudio de la violencia y el conflicto armado en Colombia, 1990-2012. *Cuad Geogr Rev Colomb Geogr*. 2014;24(1):157-172. doi:10.15446/rcdg.v24n1.47777
13. Franco S, Suarez CM, Naranjo CB, Báez LC, Rozo P. The effects of the armed conflict on the life and health in Colombia. *Cienc e Saude Coletiva*. 2006;11(2):349-361. doi:10.1590/S1413-81232006000200013
14. Restrepo JA, Spagat M, Vargas JF. *La Dinámica Del Conflicto Colombiano, 1988-2003 †*.

15. Brodzinsky S. Colombia signs historic peace deal with FARC. *The Guardian*. https://www.theguardian.com/world/2016/nov/24/colombia-signs-historic-peace-deal-with-farc-rebels. Published November 24, 2016. Accessed June 2, 2021.
16. El Espectador. Un tercio de los municipios del país está en riesgo por factores de violencia: MOE | EL ESPECTADOR. *El Espectador*. https://www.elespectador.com/politica/elecciones-colombia-2022/un-tercio-de-los-municipios-del-pais-esta-en-riesgo-por-factores-de-violencia-moe/. Published May 22, 2022. Accessed June 23, 2022.
17. Salazar LGS, Wolff J, Camelo FE. Towards violent peace? Territorial dynamics of violence in Tumaco (Colombia) before and after the demobilisation of the FARC-EP. *Conflict, Secur Dev*. 2019;19(5):497-520. doi:10.1080/14678802.2019.1661594
18. Retterg A. The Legacies of Armed Conflict on Lasting Peace and Development in Latin America | United Nations. *UN Chron*. 2016. https://www.un.org/en/chronicle/article/legacies-armed-conflict-lasting-peace-and-development-latin-america. Accessed January 6, 2021.
19. UNODC. *Global Study on Homicide 2019*. Vienna; 2019. https://www.unodc.org/documents/data-and-analysis/gsh/Booklet1.pdf. Accessed August 12, 2019.
20. Kalyvas SN. How Civil Wars Help Explain Organized Crime—and How They Do Not. *J Conflict Resolut*. 2015;59(8):1517-1540. doi:10.1177/0022002715587101
21. Hide S. Guns, cocaine and conflict: Getting healthcare to communities in rural Colombia | Blogs from Doctors Without Borders. Blogs from Doctors Without Borders. https://blogs.msf.org/bloggers/steve/guns-cocaine-and-conflict-getting-healthcare-communities-rural-colombia. Published December 18, 2020. Accessed May 20, 2021.
22. Centro Nacional de Memoria Histórica. *Modelos Para Exportar: Paramilitarismo En El Urabá Antioqueño, Sur de Córdoba, Bajo Atrato y Darién (1983-2016)*.; 2022. https://centrodememoriahistorica.gov.co/wp-content/uploads/2022/06/Modelos-para-exportar-paramilitarismo-en-el-Uraba-Antioqueo-sur-de-Córdoba-Bajo-Atrato.pdf. Accessed June 23, 2022.
23. Jurisdicción Especial Para la Paz. La JEP hace pública la estrategia de priorización dentro del Caso 03, conocido como el de falsos positivos. *Comun 019 desde 2021*. 2021. https://www.jep.gov.co/Sala-de-Prensa/Paginas/La-JEP-hace-pública-la-estrategia-de-priorización-dentro-del-Caso-03,-conocido-como-el-de-falsos-positivos.aspx. Accessed May 30, 2021.
24. Dávila-Cervantes CA, Agudelo-Botero M, Gómez-Dantés H. Trends and differences in homicide mortality in Colombia and Mexico, 1990-2016: Two Realities, One Problem. *J Interpers Violence*. May 2019:886260519847775. doi:10.1177/0886260519847775
25. Herrera M. *Homicides in Central America: Toward a Better Understanding of Territorial Trends, Causes, and Dynamics*. San Jose, Costa Rica; 2019.

https://www.wilsoncenter.org/sites/default/files/lap_homicides_cenam.pdf. Accessed August 12, 2019.
26. United Nations Office on Drugs and Crime. Intentional Homicide, 1990-2018. dataUNODC. https://dataunodc.un.org/content/data/homicide/homicide-rate. Accessed January 6, 2021.
27. In the Americas, Homicide Is the Other Killer Epidemic. https://foreignpolicy.com/2022/05/20/homicide-murder-violence-united-states-latin-america-caribbean/. Accessed June 28, 2022.
28. Sandoval LE. Socio-economics characteristics and spatial persistence of homicides in Colombia, 2000-2010. *Estud Econ*. 2018;45(1):51-77. doi:10.4067/s0718-52862018000100051
29. Vallejo K, Tapias J, Arroyave I. Trends of Rural/Urban Homicide in Colombia, 1992-2015: Internal Armed Conflict and Hints for Postconflict. *Biomed Res Int*. 2018;2018. doi:10.1155/2018/6120909
30. Urdinola BP, Torres Áviles† F, Velasco JA. The Homicide Atlas in Colombia: Contagion and Under-Registration for Small Areas. *Cuad Geogr Rev Colomb Geogr*. 2017;26(1):101-118. doi:10.15446/rcdg.v26n1.55429
31. Vallejo K, Tapias J, Arroyave I. Trends of Rural/Urban Homicide in Colombia, 1992-2015: Internal Armed Conflict and Hints for Postconflict. *Biomed Res Int*. 2018;2018. doi:10.1155/2018/6120909
32. Dugand AG, García CAÁ, Sánchez MG. *Barómetro de Las Américas, Colombia 2018: Paz, Posconflicto y Reconciliación*. Bogotá; 2019.
33. Price M, Ball P. Selection bias and the statistical patterns of mortality in conflict. *Stat J IAOS*. 2015;31(2):263-272. doi:10.3233/sji-150899
34. Dawkins S. The problem of the missing dead: *https://doi.org/101177/0022343320962159*. 2020;58(5):1098-1116. doi:10.1177/0022343320962159
35. Dawkins S. Corrigendum for Dawkins S. The problem of the missing dead: *https://doi.org/101177/00223433221103919*. 2022;58(5):002234332211039. doi:10.1177/00223433221103919
36. Rojas-Granada C, Cuesta-Borja R. Studies on the Armed Conflict and the Peace Building in Colombia from a Territorial Perspective: Approaches and Challenges. *CS*. 2021;(33):205-235. doi:10.18046/RECS.I33.3995
37. Marshall IH, Summers DL. Contemporary differences in rates and trends of homicide among European nations. In: *Handbook of European Homicide Research: Patterns, Explanations, and Country Studies*. Springer New York; 2012:39-69. doi:10.1007/978-1-4614-0466-8_4
38. De Jong JTVM. A public health framework to translate risk factors related to political violence and war into multi-level preventive interventions. *Soc Sci Med*. 2010;70(1):71-79. doi:10.1016/j.socscimed.2009.09.044
39. Archivo Nacional de Datos. Estadísticas Vitales. Departamento Administrativo Nacional de Estadísticas. https://microdatos.dane.gov.co/index.php/catalog/MICRODATOS/about_collection/22. Published 2022.

Accessed April 18, 2022.
40. Restrepo JA, Aguirre K. Homicidios y Muertes Violentas: Un análisis comparativo de las fuentes en Colombia. *Forensis Datos Para La Vida*. 2007. https://www.academia.edu/33078049/Los_Homicidios_en_Colombia_Un_análisis_comparativo_de_las_fuentes_de_información. Accessed January 2, 2021.
41. Censo Nacional de Población y Vivienda 2018. https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/censo-nacional-de-poblacion-y-vivenda-2018. Accessed March 17, 2020.
42. Centrol Nacional de Memoria Histórica. Contexto - Centro Nacional de Memoria Histórica. https://centrodememoriahistorica.gov.co/contexto/. Published 2022. Accessed April 18, 2022.
43. Centrol Nacional de Memoria Histórica. Metodología – Observatorio de Memoria y Conflicto. https://micrositios.centrodememoriahistorica.gov.co/observatorio/sievcac/metodologia/. Accessed April 18, 2022.
44. Elliot P, Wakefield J, Best N, Briggs D, eds. *Spatial Epidemiology Methods and Applications*. Oxford University Press; 2001.
45. Knorr-Held L. *Bayesian Modelling of Inseparable Space-Time Variation in Disease Risk Bayesian Modelling of Inseparable Space{Time Variation in Disease Risk*. Vol 386.; 1999.
46. Luan H, Quick M, Law J. Analyzing Local Spatio-Temporal Patterns of Police Calls-for-Service Using Bayesian Integrated Nested Laplace Approximation. *ISPRS Int J Geo-Information*. 2016;5(9):162. doi:10.3390/ijgi5090162
47. Riebler A, Sørbye SH, Simpson D, Rue H. *An Intuitive Bayesian Spatial Model for Disease Mapping That Accounts for Scaling*.; 2016. www.r-inla.org. Accessed February 7, 2021.
48. La Jurisdicción Especial para la Paz (JEP) Colombia. Caso 04: Situación territorial de la región de Urabá. https://www.jep.gov.co/especiales1/macrocasos/04.html. Published September 11, 2018. Accessed June 23, 2022.
49. Agencia de Renovación del Territorio. Informe de seguimiento a la implementación de los PDET. 2020:1-165.
50. Martínez LR. Transnational insurgents: Evidence from Colombia's FARC at the border with Chávez's Venezuela. *J Dev Econ*. 2017;126:138-153. doi:10.1016/j.jdeveco.2017.01.003
51. Briceño-León R, Villaveces A, Concha-Eastman A. Understanding the uneven distribution of the incidence of homicide in Latin America. *Int J Epidemiol*. 2008;37(4):751-757. doi:10.1093/ije/dyn153
52. Sinisterra-Ossa L, Valencia IH, Sinisterra-Ossa L, Valencia IH. Orden social y violencia en Buenaventura: entre el outsourcing criminal y la construcción de paz desde abajo. *CS*. 2020;(32):103-129. doi:10.18046/RECS.I32.3650
53. Bello Montes C. Posconflicto en Colombia: un análisis del homicidio después del proceso de

desmovilización de los grupos de autodefensas. *Rev Crim*. 2009;51(1).

54. Guerrero Velasco R. Big Data Are Reducing Homicides in Cities across the Americas. *Sci Am*. 2015;313(4):46-50. doi:10.1038/SCIENTIFICAMERICAN1015-46

55. Lindsay-Poland J. *Plan Colombia : U.S. Ally Atrocities and Community Activism*. Duke University Press; 2018.

56. Cosoy N. Has Plan Colombia really worked? *BBC News*. https://www.bbc.com/news/world-latin-america-35491504. Published February 4, 2016. Accessed June 3, 2022.

57. Hege S. Mounting Security Challenges Await Colombia's Next President | United States Institute of Peace. *United States Inst Peace*. June 2022. https://www.usip.org/publications/2022/06/mounting-security-challenges-await-colombias-next-president. Accessed June 23, 2022.

Impact of Armed Conflict on Child Mortality in Colombia, 1998-2019

INTRODUCTION

Worldwide, an estimated 452 million children—more than 1 in 6—live within 50 km of active war zones.[1] Armed conflict, defined as armed violence between organized groups, is a major cause of injury and death worldwide, posing a significant public health problem.[2,3] In addition to mortality directly resulting from violence, armed conflicts indirectly cause morbidity and mortality through more subtle means. The destruction of health infrastructure, diversion of resources, forced displacement, environmental damage to water/sanitation access, and erosion of social and economic security introduce and exacerbate risk factors for more death and morbidity off of the battlefield, particularly when civilian access to water, food, shelter, or healthcare are curtailed.[4,5] Young children, while rarely combatants, tend to be the one of the groups most vulnerable to both the direct and indirect effects of armed conflict.[6]

Under-5 child mortality rates (U5MR) are a standardized metric in global health, measured as number of deaths among children before their 5th birthday, per 1000 live births. Along with infant mortality rates, which are measured as counts of death within the first year of life per 1000 births, these metrics capture many important factors for child health in numbers that can be compared between countries or sub-nationally. Decreasing child mortality rates has been a focus of global health advocacy, and is a key indicator used to measure progress towards the UN's Sustainable Development Goals.[7] This is because the most common causes of death among young children—malnutrition, diarrhea, infectious disease, preterm birth—are largely treatable or preventable.

Child mortality—specifically U5MR—is an important outcome to study in relation to armed conflict because it captures many of the indirect effects of armed conflicts on nearby communities that are difficult to measure, such as disruption of healthcare services and public health activities, food insecurity, and forced displacement.[8,9] Infant mortality, or deaths that occur during the first year of life, generally comprise about 45% of U5MR.[10] The deleterious effects of armed conflict remain years after cessation of violence,[11] so unlike infant mortality which is a more contemporaneous outcome, U5MR encapsulates both immediate and lagged effects. Additionally, child mortality is a more sensitive indicator of armed conflicts' effects on population health than, for example, life expectancy: Child health is more vulnerable to shocks and disruptions to healthcare systems than adult health.

Both boys and girls are vulnerable to malnutrition and associated infections, as well as unexploded mines, recruitment into armed groups, and sexual violence, while evidence shows women and girls tend to be most affected by sexual violence and disruption to the provision of health services in armed conflicts.[12,13] Armed conflict exacerbates many risk factors for infectious disease transmission, and can cause public health systems to collapse, curtailing routine immunization activities or access to medical supplies.[14] A limited body of research has examined the impact of armed conflict on child health indicators, such as child mortality, malnutrition, and maternal health, mostly in sub-Saharan Africa.[15–21] However, the nature of armed conflict in these settings were generally short-term (<5 years) and limited to specific areas.[22,23] Recent reviews of the literature lament that the empirical impact of armed conflict on child health remains largely unknown, particularly in Latin America.[2,24,25]

Colombia has experienced over 7 decades of armed conflict, beginning in the 1940s and evolving over time to include multiple state, non-state, and pseudo-state (paramilitary) armed groups. The conflict, which officially ended with a peace treaty in 2016, was uniquely long-lasting, fractious, and geographically dynamic.[26–28] The United States (US) government supported the Colombian state and pseudo-state armed groups with over $10 billion in mostly military aid from 2000-2019.[29,30] The Colombian conflict was deadliest in the 1990s, due to the rise of narco-trafficking and mobilization of paramilitaries in the 1980s.[14,31]

Of the 7.6 million Colombians registered as victims of the conflict by 2016, 2.5 million, or 33%, were children (age <18).[32] Young children (age <5) comprise 20% of displaced Colombians, and 10% of the total number of civilians killed, abducted, disappeared, or tortured.[32] Despite the long-lasting armed conflict, Colombia has made substantial progress towards meeting the Millennium Development Goal of reducing U5MR. Colombia's overall U5MR decreased from 35 per 1000 live births in 1990 to 14 per 1000 live births in 2019.[33] However, the national rate masks significant subnational disparities.[34] In rural areas of Colombia, the U5MR is almost twice that of the national average.[35]

Armed conflict also disrupts the collection of data and the ability to conduct public health programs and outreach; so, empirical estimates of the impacts of specific armed conflicts on child health are limited. By leveraging the spatial and temporal heterogeneity of Colombia's armed conflict, this study estimated the impact of armed conflict on infant and child survival. An improved understanding of the child health impacts of armed conflict can inform policy and advocacy to prevent armed conflict.

METHODS

Study Setting & Population

The unit of analysis for this ecological study was municipality-year. Colombian municipalities are analogous to US counties; departments are analogous to US states. Colombia has a total of 1,122 municipalities organized into 33 departments. Bogotá, the capital of Colombia with a population over 7 million, comprises its own municipality and its own department. All municipalities were included in this study, although some municipalities (<1%) were excluded for some years, because they did not exist yet or because the number of births was ≤1.

The analytic sample consisted of 24,157 municipality-years, over the period 1998-2019. Municipality-years were included in the analysis if there were any deaths (among all ages) recorded for that municipality-year, to help ensure that death registry data was collected. The beginning of the study period was limited to 1998 due to the availability of birth records beginning in that year.

Measures

The main outcome measures, deaths among children under 5 years of age and deaths among children under 1 year of age, were obtained from Colombia's vital statistics micro-data, which are collected, processed, and hosted by the National Administrative Department of Statistics (DANE in Spanish).[36] DANE vital statistics individualized death records include data on age (by month for children <5 years), location of death, cause of death (recorded with ICD-10 codes), and some other demographics. Child deaths were measured as counts for each municipality-year, irrespective of cause, and were assigned to the child's municipality of residence.

The main independent variable, armed conflict, was based on counts of conflict-related events in each municipality-year. A municipality-year was considered 'exposed' to armed conflict if there were 10 or more conflict-related incidents occurring in that municipality. Conflict data were obtained from the Colombian government's National Center for Historical Memory (CNMH), which was mandated by Law 1448 in 2011 to compile, process, and distribute data on the armed conflict.[37] CNMH armed conflict data were collected from the National Victims' Registry, the Justice Department, interviews with survivors, death records, media reports, academic research, among others. By 2016, CNMH collected information from 382 sources and over 1,000 documents.[38] Conflict-related incidents were categorized by CNMH into one of the following categories: military actions, selective assassinations, attacks on towns, terrorist attacks, damage to civilian infrastructure/property, massacres, kidnapping, forced disappearance, recruitment of children, sexual violence, and antipersonnel mines/unexploded munitions. This last category includes exploded munitions causing injury, as well as the presence of unexploded landmines, which are particularly hazardous to children due to their toy-like appearance. Of note, conflict events did not necessarily result in fatality. Events that occurred simultaneously (e.g., kidnapping at the same time as a massacre) were assigned to the category in which the event was first reported to CNMH. One characteristic of Colombia's armed conflict has been the skewed distribution of incidents perpetrated by different armed groups; for example, paramilitary groups were associated with the most fatal incidents and with the most selective assassinations.[39] However, even non-fatal conflict events can be damaging, threatening, and may inhibit access to medical care, perhaps more so than fatal conflict-related events.[6]

Consistent with prior literature evaluating armed conflict, we took a parsimonious approach to model adjustment to avoid including factors that may be on the causal pathway between armed conflict and child mortality.[22,40] Each model in this analysis was adjusted with 3 indicators for the occurrence of severe natural disasters requiring federal emergency aid: volcano eruption and/or earthquake, hurricane and/or flooding, and droughts. These natural disasters may cause both armed conflict and child mortality, and are not a downstream effect of armed conflict. Natural disaster data were obtained from Colombia's National Unit for Disaster Risk Management (UNGRD), which included any event that was declared a public emergency and received support from the UNGRD's National Emergency Fund.[41]

Statistical Analyses

Negative binomial regression models were constructed for each count outcome—number of deaths aged <5 years, and number of deaths aged <1 year—offset by the number of births in that municipality-year. Zero-inflated negative binomial models were considered for the large amount of zeroes in the response variable, however the non-zero inflated negative binomial regression model was chosen for better model fit.

The regression model was constructed such that the parameter μ is the mean incidence rate of child death (i.e., the count of child deaths per number of births (n_i) as the offset):

$$\mu_i = n_i \mu \qquad (1)$$

$$\mu_i = \exp\left(\ln(n_i) + \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i} + \beta_5 y_i\right) \qquad (2)$$

Where x_{1i} represents the indicator for exposure to armed conflict, x_{2i} is a binary indicator for whether there were hurricanes or flooding, x_{3i} is a binary indicator for whether there was an earthquake or volcanic eruption, and x_{4i} is a binary indicator for droughts. Fixed effects for year were parameterized categorically as y_i, and standard errors were clustered by department.

For the main analysis, the outcomes of under-5 deaths and infant deaths were modeled with (i) concurrent-year conflict events, (ii) conflict events lagged to one year prior, and (iii) conflict events lagged to 5 years prior. Sub-group analyses of child deaths by sex were also performed.

Due to a small number of highly influential outliers with >365 conflict events per municipality-year, the final model was selected as that with all municipality-years, but conflict events capped to 365. The cap affected 19 municipality-years (0.08% of the sample).

Ethical approvals

This study did not meet the definition of human subjects research because all data were de-identified and publicly available.

RESULTS

The final analytic sample consisted of 24,157 municipality-years, over the period 1998-2019. A description of the analytical sample is shown below in **Table 2.1**. The distribution of causes of child mortality over time are shown in **Figure 2.1**. Additional descriptive figures are shown in the Appendix. The average (mean) count of under-5 deaths per municipality-year over the study period was 11.3 (standard deviation [SD]: ± 86.4); 39.4% of municipality-years reported at least one death of any age, but 0 deaths among children under 5 years of age. When parameterized as a child mortality rate per 1000 live births, the average (mean) under-5 mortality rate (U5MR) was 9.6 (SD ± 18.3) per 1000 births. Among infants (<1 year), the mean count of deaths per municipality-year was 9.3 (SD ± 74.3) and 49.5% of municipality-years reported 0 infant deaths. The average infant mortality rate was 6.5 (SD ± 13.9) per 1000 births.

While the data on conflict event counts were also heavily skewed, only a total of 23 municipalities (2%) had 0 conflict-related events over the entire study period (10 municipalities in the Boyacá department, 6 in Guainía, 3 in Amazonas, 2 in Cundinamarca, and 2 in Santander). The average (mean) number of armed conflict events was 9.2 (SD ± 36.8). Out of 24157 municipality-years, 10566 (43.7%) had 0 conflict events.

Results from regression analyses are presented in **Table 2.2**. Overall, exposure to armed conflict was associated with an increased risk of 51% (RR = 1.51; 95% confidence interval [95% CI] 1.31, 1.73) for child (< 5 years) death in affected municipalities. Similarly, municipalities exposed to armed conflict were associated with a 60% increased risk in infant (< 1 year) death (RR=1.60; 95% CI 1.38, 1.85). Results were robust to exclusion of large cities. On the absolute scale, this translates to an increase of 4.27 child deaths per 1,000 births (95% CI 2.86 per 1,000, 5.68 per 1,000 births), or an increase of 3.50 infant deaths per 1,000 births (95% CI 2.39 per 1,000, 4.61 per 1,000 births). Across the study period, 24.1% (95% CI 16.5%, 31.0%) of all child deaths, and 27.3% (95% CI 19.4%, 34.4%) of all infant deaths in Colombia were directly or indirectly attributable to the conflict. Nationally, over the study period, this amounts to 65,709 (95% CI 44,988 – 84,523) deaths among children <5 years, including 61,141 (95% CI 43,448 – 77,041) deaths among Colombian infants <1 year attributable to the armed conflict.

In sub-group analyses evaluating sex-specific associations of armed conflict with child and infant death, relative risks of death were similar among males and females for both children and infants. However, on the absolute scale, results suggest that the rates of male child and male infant mortality were more strongly impacted by armed conflict than rates of female child or female infant mortality (**Table 2.3**). When armed conflict exposure was lagged to correspond to conflict from one and five years prior, the RRs did not change. However, the risk differences (RD) were moderately attenuated: RD=3.59 (95% CI 2.48, 4.70 per 1,000 births) more deaths among children <5 and RD=2.88 (95% CI 1.98, 3.79 per 1,000 births) more deaths among infants <1 year than would be expected in the absence of armed conflict. When lagged to one year prior, both the relative risks and risk differences were slightly attenuated (**Tables 2.2 & 2.3**).

When examining the effects of armed conflict by cause-specific child and infant mortality, we observed some differences by underlying cause. As shown in **Table 2.4**, exposure to armed conflict was most strongly associated with deaths related to pertussis and the neonatal period. Specifically, the largest

RR was observed for deaths due to pertussis, followed by deaths due to sepsis or other newborn infections (RR=2.20; 95% CI=1.78, 2.72). Effects for deaths due to prematurity were also high with RR=1.76 (95% CI=1.48, 2.09), and the RR for intrapartum complications was moderate at 1.45 (95% CI=1.24, 1.71).

The association between armed conflict and child mortality was fairly consistent across infectious causes of mortality. Among children <5 years, municipal exposure to armed conflict was associated with a 65% increased risk of mortality due to diarrheal disease (RR=1.65; 95% CI=1.28-2.12), 69% increased risk of mortality due to malnutrition and other infectious causes (RR=1.69; 95% CI=1.45, 1.99), and 2.87-fold increase in risk of mortality due to pertussis (RR=2.87; 95% CI=1.95, 4.23) (**Table 2.4**). Among children <5, the association between armed conflict (contemporaneous, and lagged 1- and 5 years) and child mortality was not statistically significant for deaths due to tetanus (not shown), malaria, or injuries. Among infants (<1 year), armed conflicts were not statistically significantly associated with deaths due to tetanus or malaria. However, armed conflict exposure was associated with a 24% *decrease* in infant deaths due to injury (RR=0.76; 95% CI=0.59, 0.97). When looking at broader categories of underlying cause, we see the largest associations between armed conflict and deaths due to communicable diseases, followed by non-communicable diseases, for both children (<5) and infants (<12m) (**Figure 2.2**).

DISCUSSION

In this ecologic study using official records, we found a significant effect of Colombia's armed conflict on child and infant mortality rates. Overall, we found that a municipality's exposure to armed conflict was associated with about a 50% increase in child and infant mortality among that municipality. Nearly 1 in 4 child deaths were attributable to the armed conflict; this translates to excess mortality of 65,709 (95% CI 44,988 – 84,523) deaths among children <5 years, and 61,141 (95% CI 43,448 – 77,041) deaths among Colombian infants <1 year over the study period 1998-2019 that were attributable to the armed conflict.

It has been well-documented that child and infant mortality rates are higher in countries or regions experiencing conflict.[11] However, the relationship is confounded by countries in conflict more often experiencing other risk factors for child mortality, including lower GDP, state infrastructure and general socioeconomic development indicators.[42] With the exceptions of the Rwandan genocide and the Syrian civil war, armed conflicts have not usually had a clear impact on national child mortality rates.[11,43,44] Moreover, the past few decades have seen great progress in global reductions of child mortality, even in severely conflict-prone countries like the Democratic Republic of Congo (DRC) or Angola.[43]

Research on the population health effects of armed conflicts have focused on specific conflicts like those in Syria and Iraq, and multi-country studies have focused on conflicts in sub-Saharan Africa.[11,45] An analysis of armed conflicts in 35 African countries between 1995-2015 found that violent clashes within 50km during the child's first year of life was associated with higher risk of infant mortality (<1 year) than in the absence of conflict.[11] 'Chronic' conflicts, those that lasted at least 5 years, were associated with the highest increase in infant mortality of 11.7 additional infant deaths per 1000 births than would be expected in the absence of nearby armed conflict.[11] While this estimate is more than double the finding we observed of 4.27 additional child deaths per 1000, it could be explained by the methodological differences in measuring conflict and differences in the settings. Additionally, whereas Wagner et al. measured armed conflict as either present or absent within a set distance of the child's birth place, our study measured child and infant deaths attributable to the presence of armed conflict in a given municipality-year. If we applied our results to a municipality-year in which 22 conflict-related incidents occurred in a given year, which was observed for 93 municipalities in our sample, our findings were consistent.

There is less agreement on how long the effects of armed conflict last. In the multi-country analysis, infant mortality risk was elevated for up to 8 years after the conflict event.[11] In our lagged analysis, we found largely consistent and slightly attenuating associations between armed conflict incidents and child and infant mortality. This difference in findings may be attributable to some unique characteristics of Colombia's armed conflict, such as widespread exposure, chronic persistence and massive population displacement. In 2018, 40% of Colombians reported having been a victim of the armed conflict, defined as having been forcibly displaced or having a family member killed or kidnapped due to the conflict.[46] It may be more difficult to disentangle the effects of repeated or widespread exposures to armed conflict in Colombia, which was more common than armed conflicts in sub-Saharan Africa which tended to be more acute in timing.

Some studies have examined the impact of Colombia's armed conflict on demographic indicators, including fertility,[47] contraception use,[48] educational outcomes,[49] and most recently, maternal and infant health indicators.[8] In their mixed methods study, Ramos Jaraba et al. (2020) did not find statistically significant differences in infant mortality among conflict-affected municipalities, but did observe increased rates of teenage pregnancy and maternal mortality in municipalities with higher levels of conflict.[8] In support of these findings, we found that deaths due to neonatal period-related causes, such as prematurity, intrapartum-complications, congenital anomalies, and sepsis and other newborn infections were the most strongly associated with armed conflict. The delivery of health services to pregnant women are necessary for both maternal and infant health outcomes, but are crucial in conflict-affected areas. The availability of emergency obstetric services in particular has been found to be critically impacted by armed conflict in Colombia and Mexico.[40,50]

While armed conflict was not statistically significantly associated with fatal injuries among children <5, armed conflict was statistically significantly *negatively* associated with fatal injuries among infants. While the magnitude of the relative risk was not large, this could be due to several reasons. Infants who otherwise would succumb to fatal injury in their first year of life might be more likely to first die from causes that have increased risk, such as prematurity or malnutrition. On the other hand, infants in areas exposed to armed conflicts might be more supervised, or have more vigilant parents compared to non-conflict affected areas, and therefore less likely to become accidentally injured. Another reason could be that infant or child deaths due to injury might be less likely to be recorded in areas affected by armed conflict, which are also less likely to have strong state presence and therefore access to official birth and death registration services.

These findings should be taken in view of some limitations. First, this analysis relied on official death registries for child mortality data. While Colombia's vital statistics have been validated, they may be less reliable in areas not controlled by the state during the armed conflict. To address this limitation, municipality-years were included in this analysis only if there was at least one death, of any age, recorded to increase the likelihood that child deaths were properly recorded. In Colombia, forced displacement caused significant migration patterns and population changes over the study period. However, deaths recorded were attributed to the municipality of residence of the decedent, regardless of where the death occurred. Some child and infant deaths were undoubtedly not captured by official death records, but this biases results toward the null, so true effects may be larger than estimated.

Conclusion

While some studies have shown disproportionately poor child health outcomes in countries that have experienced armed conflict, this is one of the first studies to quantify the impact of armed conflict on child mortality in Colombia.[14,51] The armed conflict in Colombia, which has lasted over half a century, is more chronic, complex, and localized than many of the armed conflicts that have been studied in relation to child health. One hallmark of Colombia's armed conflict is the dynamic spatiotemporal distribution of violence: armed guerrilla groups mostly concentrated in rural areas with geostrategic territorial features, with considerable movement over time.[27,52] This difference-in-differences study leveraged these changes in conflict intensity over time and space and compared municipalities to themselves before/after conflict, and to other municipalities contemporaneously, which improves on prior descriptive literature by incorporating a counter-factual. This improved understanding of the relationship between armed conflict and child mortality outcomes may be helpful to inform this program and other public health planning as Colombia moves through its post-conflict period.[8,53,54]

Beyond mortality, millions of children in Colombia have been harmed by the armed conflict, through displacement, kidnappings, sexual violence, recruitment into armed groups, explosive devices, and other means. For civilians who live in regions affected by Colombia's armed conflict, there is almost no facet of life that is unaffected by the conflict or its sequelae.[34] Because the indirect effects of conflict on health tend to be long-lasting,[24] mortality may be the most measurable outcome by official records, but likely belies other negative health outcomes. Nevertheless, efforts such as the Colombian government's special designation program to prioritize municipalities historically affected by armed conflict for initiatives and investments, have already demonstrated positive gains in reducing child and infant mortality.[55]

More than two thirds of the world's children live in countries with active armed conflict.[1] It is more important than ever for policy makers, violence prevention advocates, and health professionals to understand the ways in which armed conflict directly and indirectly undermines child health. Unlike natural disasters, armed conflicts are neither spontaneous nor inevitable. Upstream determinants of armed conflict include socioeconomic inequality and disenfranchisement, but most importantly, arms proliferation.[56] It must be noted that the United States, through the "Plan Colombia" announced in 1999, has delivered over $10 billion to Colombia's military through 2021.[29] This US-sponsored military crackdown coincided with the peak of extra-judicial killings carried out by Colombia's police and military.[57] US-made firearms have been used to perpetrate countless armed conflict events, including many of the conflict events in this study.[58]

Table 2.1. Description of analytical sample, N=24157 municipality-years

	Mean (± SD) or **n (%)**	**Median (IQR)**	**Range**
Total population	39428 (± 236705)	12362 (6628, 24769)	0, 7592871
Number of births	627 (± 3809)	167 (80, 380)	2†, 136458
Child deaths <5	11 (± 86)	1 (0, 3)	0, 3441
Child mortality rate per 1000 births	9.6 (± 18.3)	4.8 (0, 13.0)	0, 519
Child deaths <1	9 (± 74)	1 (0, 2)	0, 2996
Infant mortality rate per 1000 births	6.5 (±13.9)	1.1 (0, 8.7)	0, 500
Armed conflict events	9 (± 37)	1 (0, 6)	0, 2092
Armed conflict victims	11 (± 43)	1 (0, 7)	0, 2403
Hurricane or flood, n (%)	9616 (39.8%)		
Volcano or earthquake, n (%)	4165 (17.2%)		
Drought, n (%)	342 (1.4%)		

† Municipalities needed to have had at least 2 births in a year to be included, due to division problems with offset term because ln(1)=0
SD = standard deviation; IQR = interquartile range

Table 2.2. Negative binomial regression results: Associations between conflict exposure and child and infant deaths, N=23939

	RR (95% CI)	**P-value**
Contemp.		
Child (<5)	1.51 (1.31, 1.73)	<0.001
Infant (<1)	1.60 (1.38, 1.85)	<0.001
1 year lag		
Child (<5)	1.52 (1.32, 1.74)	<0.001
Infant (<1)	1.61 (1.39, 1.87)	<0.001
5 year lag		
Child (<5)	1.53 (1.34, 1.76)	<0.001
Infant (<1)	1.63 (1.40, 1.89)	<0.001

All models adjusted for natural disaster indicators of hurricane/flood, volcano/earthquake, or drought; and year fixed effects

Conflict exposure: >=10 events/year

Table 2.3. Associations between conflict exposure and child and infant deaths, by sex

	RD[†]	95% CI	P-value
Contemporaneous			
Child (<5) overall	**4.27**	**2.86, 5.68**	<0.001
Child (<5) -- males	4.61	3.01, 6.21	<0.001
Child (<5) -- females	3.96	2.64, 5.27	<0.001
Infant (<1) overall	**3.50**	**2.39, 4.61**	<0.001
Infant (<1) -- males	3.82	2.54, 5.09	<0.001
Infant (<1) -- females	3.25	2.21, 4.29	<0.001
1-year lag			
Child (<5) overall	**4.14**	**2.78, 5.50**	<0.001
Child (<5) -- males	4.67	3.15, 6.20	<0.001
Child (<5) -- females	3.68	2.37, 4.99	<0.001
Infant (<1) overall	**3.40**	**2.33, 4.48**	<0.001
Infant (<1) -- males	3.86	2.63, 5.09	<0.001
Infant (<1) -- females	3.04	2.01, 4.06	<0.001
5-year lag			
Child (<5) overall	**3.59**	**2.48, 4.70**	<0.001
Child (<5) -- males	3.99	2.75, 5.23	<0.001
Child (<5) -- females	3.31	2.19, 4.43	<0.001
Infant (<1) overall	**2.88**	**1.98, 3.79**	<0.001
Infant (<1) -- males	3.24	2.20, 4.27	<0.001
Infant (<1) -- females	2.66	1.76, 3.56	<0.001

† **Computed per 1,000 births**. RD = risk difference; CI = confidence interval
All models adjusted for natural disaster indicators of hurricane/flood, volcano/earthquake, or drought; and year fixed effects

Table 2.4. Associations between armed conflict and child (<5) mortality by select causes

	Contemporaneous		1-year lag		5-year lag	
	RR (95% CI)	P-value	RR (95% CI)	P-value	RR (95% CI)	P-value
Diarrheal disease	1.65 (1.28, 2.12)	<0.001	1.75 (1.33, 2.31)	<0.001	1.62 (1.20, 2.20)	0.002
Pertussis	2.87 (1.95, 4.23)	<0.001	2.68 (1.67, 4.30)	<0.001	3.34 (2.08, 5.36)	<0.001
Malaria	0.95 (0.42, 2.18)	0.909	1.51 (0.72, 3.16)	0.278	1.31 (0.62, 2.79)	0.477
Lower resp. tract infection	1.57 (1.32, 1.86)	<0.001	1.62 (1.36, 1.93)	<0.001	1.71 (1.47, 2.00)	<0.001
Prematurity	1.76 (1.48, 2.09)	<0.001	1.79 (1.50, 2.15)	<0.001	1.78 (1.47, 2.15)	<0.001
Intrapartum complications	1.45 (1.24, 1.71)	<0.001	1.49 (1.25, 1.77)	<0.001	1.46 (1.24, 1.73)	<0.001
Sepsis/ newborn infections	2.20 (1.78, 2.72)	<0.001	2.22 (1.79, 2.74)	<0.001	2.44 (1.93, 3.07)	<0.001
Malnutrition other inf. causes	1.69 (1.45, 1.99)	<0.001	1.71 (1.46, 1.99)	<0.001	1.77 (1.52, 2.07)	<0.001
Congenital anomalies	1.55 (1.28, 1.88)	<0.001	1.54 (1.26, 1.89)	<0.001	1.68 (1.38, 2.05)	<0.001
Other non-comm. disease	1.47 (1.29, 1.67)	<0.001	1.52 (1.32, 1.76)	<0.001	1.59 (1.37, 1.83)	<0.001
Injuries	1.06 (0.89, 1.26)	0.523	1.04 (0.87, 1.24)	0.642	1.05 (0.90, 1.21)	0.553

All models adjusted for natural disaster indicators of hurricane/flood, volcano/earthquake, or drought; and year fixed effects

Figure 2.1. Child (<5 Years) Deaths in Colombia by Cause, 1998-2019

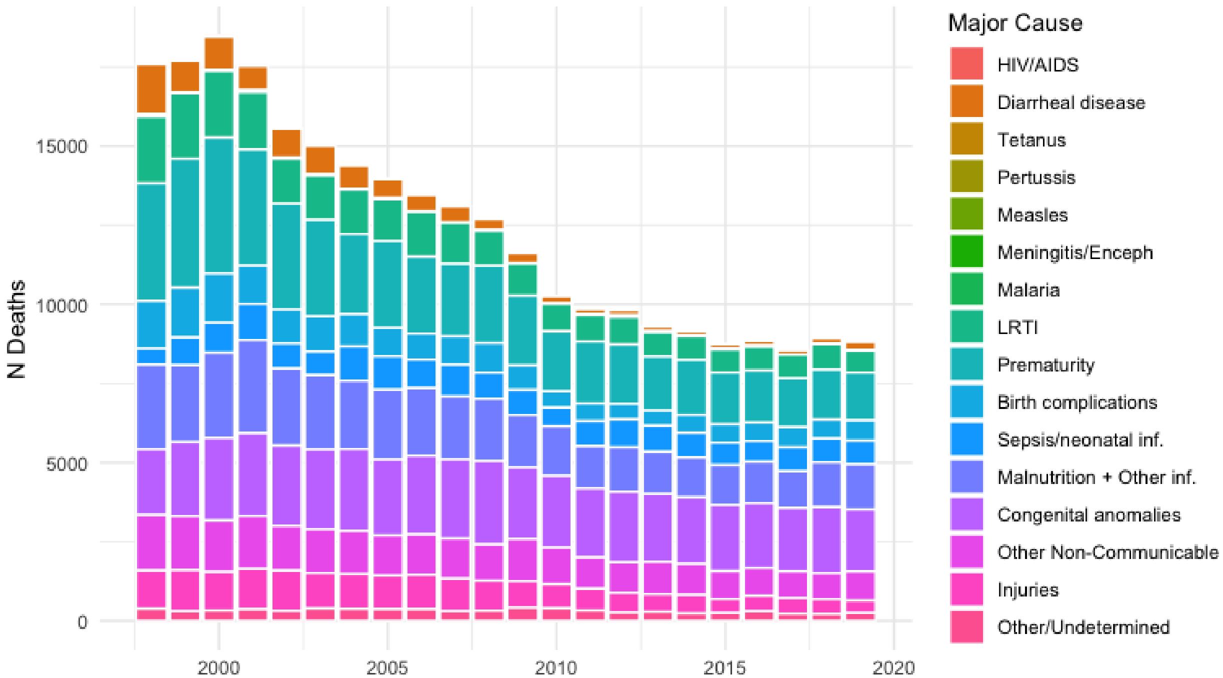
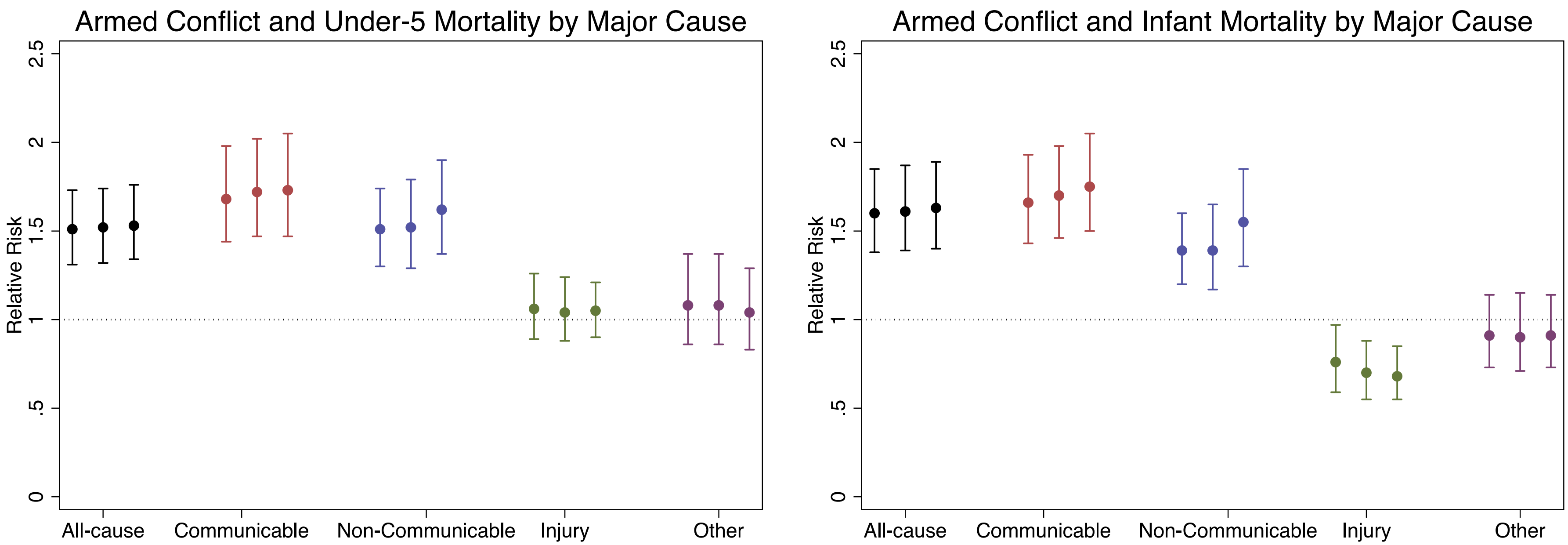


Figure 2.2. Association between armed conflict and child and infant mortality, by major cause



Note: Bars correspond to (left to right): contemporaneous armed conflict, conflict one year prior, and conflict 5 years prior

REFERENCES

1. Østby G, Rustad SA, Arasmith A. *Children Affected by Armed Conflict, 1990–2020*. Oslo; 2021. https://www.prio.org/publications/12884. Accessed June 3, 2022.
2. Murray CJL, King G, Lopez AD, Tomijima N, Krug EG. Armed conflict as a public health problem. *Br Med J*. 2002;324(7333):346-349. doi:10.1136/bmj.324.7333.346
3. Garry S, Checchi F. Armed conflict and public health: into the 21st century. *J Public Health (Bangkok)*. 2020;42(3):e287-e298. doi:10.1093/pubmed/fdz095
4. Gordon S, Baker A, Duten A, Garner P. Study exploring the evidence relating Health and Conflict interventions and outcomes Commissioned by the UK Cross Government. 2010.
5. Leaning J, Guha-Sapir D. Natural Disasters, Armed Conflict, and Public Health. *N Engl J Med*. 2013;369(19):1836-1842. doi:10.1056/nejmra1109877
6. Kadir A, Shenoda S, Goldhagen J, Pitterman S, SECTION ON INTERNATIONAL CHILD HEALTH. The Effects of Armed Conflict on Children. *Pediatrics*. 2018;142(6). doi:10.1542/peds.2018-2586
7. *The Sustainable Development Goals Report*.
8. Ramos Jaraba SM, Quiceno Toro N, Ochoa Sierra M, et al. Health in conflict and post-conflict settings: Reproductive, maternal and child health in Colombia. *Confl Health*. 2020;14(1). doi:10.1186/s13031-020-00273-1
9. Franco S, Mercedes Suarez C, Naranjo CB, Carolina Báez L, Rozo P. The effects of the armed conflict on the life and health in Colombia Os efeitos do conflito armado sobre a vida e a saúde na Colômbia. *Cienc e Saude Coletiva*. 2006;11(2):349-361.
10. Liu L, Oza S, Hogan D, et al. Global, regional, and national causes of under-5 mortality in 2000–15: an updated systematic analysis with implications for the Sustainable Development Goals. *Lancet*. 2016;388(10063):3027-3035. doi:10.1016/S0140-6736(16)31593-8
11. Wagner Z, Heft-Neal S, Bhutta ZA, Black RE, Burke M, Bendavid E. Armed conflict and child mortality in Africa: a geospatial analysis. *Lancet*. 2018;392(10150):857-865. doi:10.1016/S0140-6736(18)31437-5
12. United Nations High Commissioner for Refugees (UNHCR). *Humanitarian Protection in Armed Conflict*.; 2021.
13. Rivillas JC, Rodriguez RD, Song G, Martel A. How do we reach the girls and women who are the hardest to reach? Inequitable opportunities in reproductive and maternal health care services in armed conflict and forced displacement settings in Colombia. *PLoS One*. 2018;13(1):e0188654. doi:10.1371/journal.pone.0188654
14. Franco S, Suarez CM, Naranjo CB, Báez LC, Rozo P. The effects of the armed conflict on the life and health in Colombia. *Cienc e Saude Coletiva*. 2006;11(2):349-361. doi:10.1590/S1413-81232006000200013
15. Minoiu C, Shemyakina ON. Armed conflict, household victimization, and child health in CÔte d'Ivoire. *J Dev Econ*. 2014;108:237-255. doi:10.1016/j.jdeveco.2014.03.003
16. Bundervoet T, Verwimp P, Akresh R. Health and civil war in rural Burundi. *J Hum Resour*. 2009;44(2):536-563. doi:10.3368/jhr.44.2.536
17. Sato R. Effect of armed conflict on vaccination: Evidence from the Boko haram insurgency in northeastern Nigeria. *Confl Health*. 2019;13(1). doi:10.1186/s13031-019-0235-8

18. Namasivayam A, Arcos González P, Castro Delgado R, Chi PC. The Effect of Armed Conflict on the Utilization of Maternal Health Services in Uganda: A Population-based Study. *PLoS Curr*. 2017;9. doi:10.1371/currents.dis.557b987d6519d8c7c96f2006ed3c271a
19. Akresh R, Lucchetti L, Thirumurthy H. Wars and child health: Evidence from the Eritrean-Ethiopian conflict. *J Dev Econ*. 2012;99(2):330-340. doi:10.1016/j.jdeveco.2012.04.001
20. Cetorelli V. The impact of the Iraq War on neonatal polio immunisation coverage: a quasi-experimental study. *J Epidemiol Community Heal*. 2015:226-331. doi:10.1136/jech-2013-203174
21. Kinyoki DK, Moloney GM, Uthman OA, et al. Conflict in Somalia: Impact on child undernutrition. *BMJ Glob Heal*. 2017;2(2):262. doi:10.1136/bmjgh-2016-000262
22. Wagner Z, Heft-Neal S, Wise PH, et al. Women and children living in areas of armed conflict in Africa: a geospatial analysis of mortality and orphanhood. *Lancet Glob Heal*. 2019;7(12):e1622-e1631. doi:10.1016/S2214-109X(19)30407-3
23. Gates S, Hegre H, Nygård HM, Strand H. Development Consequences of Armed Conflict. *World Dev*. 2012;40(9):1713-1722. doi:10.1016/j.worlddev.2012.04.031
24. Wagner Z, Heft-Neal S, Bhutta ZA, Black RE, Burke M, Bendavid E. Armed conflict and child mortality in Africa: a geospatial analysis. *Lancet*. 2018;392(10150):857-865. doi:10.1016/S0140-6736(18)31437-5
25. Boerma T, Tappis H, Saad-Haddad G, et al. Armed conflicts and national trends in reproductive, maternal, newborn and child health in sub-Saharan Africa: what can national health surveys tell us? *BMJ Glob Heal*. 2019;4(Suppl 4):e001300. doi:10.1136/bmjgh-2018-001300
26. Rettberg A, Ortiz-Riomalo JF. Golden Opportunity, or a New Twist on the Resource-Conflict Relationship: Links Between the Drug Trade and Illegal Gold Mining in Colombia. *World Dev*. 2016;84:82-96. doi:10.1016/j.worlddev.2016.03.020
27. Castilla CE, Salazar LGS. *Dinámica Espacial de Las Muertes Violentas En Colombia : 1990-2005*. Bogotá: Vicepresidencia de la República; 2008.
28. Franco SA. Momento y Contexto de la Violencia en Colombia. *Rev Cuba Salud Pública*. 2003;29(1). http://scielo.sld.cu/scielo.php?pid=S0864-34662003000100004&script=sci_arttext&tlng=en. Accessed January 3, 2021.
29. Brennan C. The United States' Role in Colombia's Forever War. *Progressive*. October 2021. https://progressive.org/latest/united-states-role-colombia-forever-war-brennan-211004/. Accessed June 3, 2022.
30. US Aid to Colombia. https://i1.wp.com/colombiapeace.org/wp-content/uploads/2021/02/201111_andes_notes.001.jpeg?ssl=1. Accessed June 3, 2022.
31. Restrepo JA, Spagat M, Vargas JF. *La Dinámica Del Conflicto Colombiano, 1988-2003 †*.
32. *Childhood in the Time of War: Will the Children of Colombia Know Peace at Last?*; 2016.
33. Sharrow D, Hug L, Liu Y, You D. *Levels & Trends in Child Mortality: Report 2020*.; 2020.
34. García-Balaguera C. La salud como derecho en el postconflicto colombiano. *Rev Salud Publica*. 2018;20(6):778-784. doi:10.15446/rsap.v20n6.67777
35. Ministro de Salud y Protección Social. *Encuesta Nacional de Demografía y Salud: Tomo I*. Bogotá, Colombia;

2016.

36. Archivo Nacional de Datos. Estadísticas Vitales. Departamento Administrativo Nacional de Estadísticas. https://microdatos.dane.gov.co/index.php/catalog/MICRODATOS/about_collection/22. Published 2022. Accessed April 18, 2022.

37. Centrol Nacional de Memoria Histórica. Contexto - Centro Nacional de Memoria Histórica. https://centrodememoriahistorica.gov.co/contexto/. Published 2022. Accessed April 18, 2022.

38. Centrol Nacional de Memoria Histórica. Metodología – Observatorio de Memoria y Conflicto. https://micrositios.centrodememoriahistorica.gov.co/observatorio/sievcac/metodologia/. Accessed April 18, 2022.

39. Aguirre K, Muggah R, Restrepo J, Spagat M. Colombia's Hydra: the many faces of gun violence. In: *Small Arms Survey 2006: Unfinished Business*. ; 2006:214-245.

40. Ramos Jaraba SM, Toro NQ, Sierra MO, et al. Health in conflict and post-conflict settings: reproductive, maternal and child health in Colombia. doi:10.1186/s13031-020-00273-1

41. Unidad Nacional para la Gestión del Riesgo de Desastres. Manejo de Desastres. http://portal.gestiondelriesgo.gov.co/Paginas/Manejo-de-Desastres.aspx. Published 2022. Accessed April 18, 2022.

42. Schell CO, Reilly M, Rosling H, Peterson S, Mia A, Ekstro¨m EE. Socioeconomic determinants of infant mortality: A worldwide study of 152 low-, middle-, and high-income countries. doi:10.1080/14034940600979171

43. Wang H, Bhutta ZA, Coates MM, et al. Global, regional, national, and selected subnational levels of stillbirths, neonatal, infant, and under-5 mortality, 1980–2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet*. 2016;388(10053):1725-1774. doi:10.1016/S0140-6736(16)31575-6

44. Guha-Sapir D, Schlüter B, Rodriguez-Llanes JM, Lillywhite L, Hicks MH-R. Patterns of civilian and child deaths due to war-related violence in Syria: a comparative analysis from the Violation Documentation Center dataset, 2011–16. *Lancet Glob Heal*. 2018;6(1):e103-e110. doi:10.1016/S2214-109X(17)30469-2

45. Boerma T, Tappis H, Saad-Haddad G, et al. Armed conflicts and national trends in reproductive, maternal, newborn and child health in sub-Saharan Africa: what can national health surveys tell us? *BMJ Glob Heal*. 2019;4(Suppl 4):e001300. doi:10.1136/bmjgh-2018-001300

46. Dugand AG, García CAÁ, Sánchez MG. *Barómetro de Las Américas, Colombia 2018: Paz, Posconflicto y Reconciliación*. Bogotá; 2019.

47. Castro Torres AF, Urdinola BP. Armed Conflict and Fertility in Colombia, 2000–2010. *Popul Res Policy Rev*. 2019;38(2):173-213. doi:10.1007/s11113-018-9489-x

48. Svallfors S, Billingsley S. Conflict and Contraception in Colombia. *Stud Fam Plann*. 2019;50(2):87-112. doi:10.1111/sifp.12087

49. Rodriguez C, Torres FS. *Armed Conflict Exposure, Human Capital Investments and Child Labor: Evidence from Colombia Decentralization and Development View Project*.; 2009. http://economia.uniandes.edu.co. Accessed December 30, 2020.

50. Brentlinger PE, Javier Sánchez-Pérez H, Arana Cedeño M, et al. Pregnancy outcomes, site of delivery, and community schisms in regions affected by the armed conflict in Chiapas, Mexico. *Soc Sci Med*. 2005;61(5):1001-1014. doi:10.1016/J.SOCSCIMED.2004.12.022

51. Ngo NV, Pemunta NV, Muluh NE, Adedze M, Basil N, Agwale S. Armed conflict, a neglected determinant of childhood vaccination: some children are left behind. *Hum Vaccin Immunother*. December 2019:1-10. doi:10.1080/21645515.2019.1688043
52. Salas Salazar LG. Lógicas territoriales y relaciones de poder en el espacio de los actores armados: un aporte desde la geografía política al estudio de la violencia y el conflicto armado en Colombia, 1990-2012. *Cuad Geogr Rev Colomb Geogr*. 2014;24(1):157-172. doi:10.15446/rcdg.v24n1.47777
53. Bell V, Méndez F, Martínez C, Palma PP, Bosch M. Characteristics of the Colombian armed conflict and the mental health of civilians living in active conflict zones. *Confl Health*. 2012;6(1):1-8. doi:10.1186/1752-1505-6-10
54. Salazar LGS, Wolff J, Camelo FE. Towards violent peace? Territorial dynamics of violence in Tumaco (Colombia) before and after the demobilisation of the FARC-EP. *Conflict, Secur Dev*. 2019;19(5):497-520. doi:10.1080/14678802.2019.1661594
55. Agencia de Renovación del Territorio. Informe de seguimiento a la implementación de los PDET. 2020:1-165.
56. United Nations Security Council. Rapid Spread of Small Arms, Light Weapons Still Threatening World Peace, Exacerbating Plight of Civilians in Conflict Zones, Disarmament Chief Tells Security Council. In: *Security Council 8874th Meeting*. New York, NY; 2021. https://www.un.org/press/en/2021/sc14656.doc.htm. Accessed June 4, 2022.
57. Lindsay-Poland J. *Plan Colombia : U.S. Ally Atrocities and Community Activism*. Duke University Press; 2018.
58. Egar S. *Issue Brief: U.S. Security Assistance to Colombia Amidst a Faltering Peace*.; 2021. https://securityassistance.org/publications/issue-brief-u-s-security-assistance-to-colombia-amidst-a-faltering-peace/. Accessed June 3, 2022.