Inside the War on Drugs:
Effectiveness and Unintended Consequences of a Large Illicit Crops Eradication Program in Colombia

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Abstract

This article reports the results of an econometric evaluation of the effects of *Plan Colombia*, the largest US aid package ever received by a country in the western hemisphere. We assess how the aerial spraying of illegal crops affects both the size of the land cultivated with coca bushes as well as the dynamics of localized violence in the context of Colombia's armed conflict. In particular, we show that the marginal effect of spraying of one acre of coca reduces the cultivated area by about 11 percent of an acre. Since aerial spraying may shift coca crops to neighboring municipalities, this results should be interpreted as a local effect. In addition, since the same coca fields are often sprayed multiple times, this figure constitutes a lower bound of the mean eradicating effect of aerial spraying, To study the impact on conflict dynamics, we examine both the short-term and the long-term effects of crop spraying. Our results suggest that guerrilla-led violence increases both in the short and the long term. We interpret this result as evidence that the guerrilla tries to hold on violently to the control of an asset that is of first order importance for their survival.

Keywords: War on Drugs, Plan Colombia, Illicit Crops, Conflict, GMM.
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1 Introduction

In this article we conduct an econometric evaluation of *Plan Colombia* (PC): the largest aid package ever received by a country in the western hemisphere. PC was launched in 1999 as a $7.5 billion policy-package co-financed by the American and the Colombian governments, with the stated goal of reducing by 50 percent the cultivation, processing, and distribution of illegal narcotics over a period of six years, starting in 2000. Indeed, with PC the US effectively took the *War on Drugs* to the country producing 90 percent of the cocaine that reached its border (GAO, 2008a). As a byproduct, by cutting their main source of finance, another important goal of PC was to weaken the illegal armed groups that challenge the Colombian state, and hence to ameliorate the intensity of the country's civil strife. While PC has been the subject of continuous political debate both in Colombia and the US, there are surprisingly very few quantitative evaluations of the program with which to back such debates.[1] Indeed, after over a decade, we know very little on whether PC has been effective or not in achieving its goals, and what elements of PC if any could be improved. Studying the effectiveness of PC is important as most of the cocaine that enters the US comes from Colombia.

We assess both the short run and the long run effects of PC in terms of the two outcomes the program intended to affect: the production of coca bushes and the dynamics of the Colombian armed conflict. We do so by focusing on one particular but well defined policy instrument: the aerial spraying of illegal-crop fields, over the initial period of PC (1999-2005). Aerial spraying is the most important eradication tool in Colombia, as it allows operating in remote and insecure areas where manual eradication is cost prohibitive or too dangerous.

Using satellite images on the location and extension of coca fields, as well as event-based data on the aerial spraying of coca fields and a rich longitudinal dataset on the dynamics of the internal conflict, we investigate the long-term effect of the aerial spraying program on coca production and violence.[2] The violence outcomes studied are attacks performed by guerrilla groups, clashes between these groups and government forces, and casualties from the civilian and the combatant population.[3]

[1] One exception is Mejía and Restrepo (2010) who calibrate a general equilibrium model of the wholesale market of cocaine to conclude that PC has been ineffective in reducing the amount of drugs that reach the border of the US in spite if the eradication efforts in Colombia.

[2] While the satellite measures of coca cultivation are available only annually, the rest of the variables have daily frequency. Hence, we can only estimate the long-term effect of the eradication program on the size of illegal cropping. Instead, the effect on violence can be estimated both in the short and the long-term.

[3] We limit our analysis to guerrilla violence for two main reasons. First, guerrilla groups have been associated with the complete chain of drug production and trafficking, even since before the the big Colombian drug cartels were dismantled in the first half of the 1990s (Vargas, 2009). Second, the other major illegal group, composed by paramilitary militias under the umbrella organization called AUC, started a peace

Our results show that one additional acre of coca eradicated reduces the cultivated area by about 11 percent of an acre on the margin. The mean effect of the eradication effort on coca crops is however plausibly larger, as there is evidence that the same coca fields are often sprayed multiple times (Nivia, 2001). However, as the available data on aerial spraying is aggregated at the municipal level and it is not geo-referenced, it is impossible to know for certain the average number of episodes the same field is sprayed. Hence, we are only able to report the marginal effect which is most likely a lower bound of the mean effect of the eradication program on the size of coca crops. Moreover, while it is also possible that the eradication efforts cause substitution of coca crops to neighboring municipalities, our estimates do not account for this effect. Indeed, the available data only allows us to estimate local effects, and this is how our results should be interpreted. In any case, our results may explain the puzzle that, in spite of the massive spraying of coca crops in Colombia, the wholesale and retail market prices have stayed relatively stable (Mejía and Posada, 2008).

In terms of the effect of the aerial spraying program on violence our estimates indicate that guerrilla violent activity increases in sprayed areas. The guerrilla reaction is in turn challenged by the government, which increases two-sided clashes between the government and the guerrilla as well as the killing of combatants. This result is consistent with the hypothesis that while coca eradication weakens the guerrilla by cutting its main source of finance, localized violence increases as the guerrilla tries to hold on to control of the strategic coca fields.

The link between coca production and violence in Colombia has been studied before. Using difference-in-differences, Angrist and Kugler (2008) assess the consequences on crime rates and labor market outcomes of the shift in coca production from neighboring countries to Colombia in the early 1990s. They conclude that income shock derived from coca production, while generating few economic benefits, fueled local violence. More recently, using an instrumental variables approach, Reyes (2011) estimated the effect of eradication on coca cultivation, concluding that eradication increases the size of the crops by almost the same amount of area eradicated.[4]

We also investigate the short-term effect of the spraying program on violence using *daily* data on coca spraying and conflict dynamics, disaggregated across over 1,000 municipalities

process and demobilization campaigns since 2003, and hence its is not active for our whole period of analysis.

[4]The instrument proposed by Reyes (2011) is the distance from each field to the closest eradication aerial base. While this arguably affects the cost of spraying, the location of these bases is determined by pre-existing commercial and military airports. This challenges the validity of the exclusion restriction. Indeed, coca fields are arguably less likely to have concentrated in the surroundings of commercial and military airports. In turn, the fewer and more sparse coca crops are, the less likely it is for them to be sprayed. In addition, Reyes (2011) does not control for municipality fixed effects and his analysis focuses on a different period (2001-2006).

from 1999 to 2005.[5] For this purpose we create two "event" windows: the *preparation stage* window and the *post-eradication* window. This allows us to measure by how much high frequency violence outcomes changed around the days that the spraying was carried out in excess to the average behavior observed in the places affected by the spraying program.

Echoing the long-term results, the short-term estimates also suggest that guerrilla activity increases in sprayed areas. However, in contrast to the long-term, in the short term the government does not seem to challenge the guerrilla reaction. This is consistent with the hypothesis that short-term eradication efforts at the dawn of PC were largely unaccompanied by military presence for consolidation purposes, something that the current government (2010-2014) has explicitly addressed.[6]

Our dataset includes much of the information on coca and conflict the Colombian government observed during the period of study. This is crucial in the setting of this article as the outcomes studied here are most likely taken into account to define the places where policies are targeted as well as their intensities.

The rest of the paper is organized as follows. Section 2 gives details on the relationship between drugs and violence in Colombia and describes PC, especially its illegal crop spraying component. Section 3 describes the data sources. Section 4 presents the empirical strategy for the long-term analysis and the main results on the effect of aerial spraying on coca cultivation and conflict violence. Section 5 presents the empirical strategy for the short-term analysis and the main results on the effect of spraying events on immediate violent responses. Finally, section 6 concludes.

2 Background

2.1 Illegal Drugs and Violence in Colombia

Illegal armed groups in Colombia finance their activity with the proceeds of drug trafficking. In fact, the link between illegal drugs and armed conflict in Colombia is well known. For instance, the Revolutionary Armed Forces of Colombia (known by the Spanish acronym, FARC) produce about 60 percent of the cocaine exported from Colombia to the US. FARC is in fact Colombia's largest insurgent organization and in 2001 was designated by the US Department of Justice a *terrorist* organization (GAO, 2009).

FARC got involved in the cocaine business when the Medellin cartel expanded its operation to southeastern Colombia around the end of the 1970s (Arreaza et al., 2011). At first,

[5] The municipality is the smallest administrative unit of Colombia. It is equivalent to the US county.

[6] Interview with Álvaro Balcázar, director of the government's Administrative Unit of Consolidation (UACT, from the Spanish acronym), October 3, 2011.

FARC's involvement was limited to taxing farmers with 10 percent of coca base production (ICG, 2005). In fact, during the VII FARC's Conference in 1982, the group exhorted its fronts to get involved in this kind of taxation for financing purposes (Pizarro, 2006; Pecaut, 2008). Later on, at the VIII Conference in 1993, FARC decided to get involved in other stages of the cocaine trafficking chain besides taxing production. Different fronts specialized in different activities, including growing coca bushes, transforming coca base into cocaine in illegal laboratories, controlling traffic routes and exporting the final product to the foreign markets. Indeed, by the late 1990s each local front commander was responsible for financing his own operation (Felbab-Brown, 2010).

FARC devote around fifty percent of its force to drug-trafficking activities (Bibes, 2000). Drug profits have allowed FARC to expand modernize its military equipment. For example, a single airdrop in Russia in October 1999, received by a local mafia, secured the insurgent group a 50-million dollars worth shipment of AK-47s (Berry, et al. 2002).

2.2 The aerial spraying of coca fields

The PC strategy against coca crop cultivation includes a number of measures ranging from aerial spraying, to forced or voluntary manual eradication (including "alternative development" and crops' substitution programs), and scaling up the military initiative against drug producers (DNE, 2007).

In this article we study the efficacy of the aerial eradication component of PC, while controlling for the roll out of the other components in the form of crop substitution programs and the expansion of the country's military capacity.

The aerial eradication program is designed to inflict significant economic damage to both the farming and refining segments of the cocaine industry. A damage large enough to produce both a sizable reduction of cocaine production in the medium term, and ultimately bankruptcy in the longer term for producers. The program is carried out by the Colombian Anti-Narcotics Police (DIRAN) with extensive financial and operative support from the US State Department. Detailed aerial reconnaissance of cultivation areas precedes all spray missions. Missions are cancelled if wind speed at the originating airport is greater than 10mph, if relative humidity is below 75 percent, or if temperature is over 32 degrees Celsius (90 Fahrenheit). For efficacy reasons, spraying missions are planned so as to avoid spraying wet coca. The ideal conditions include no rain on the targeted fields from two hours before to four hours after the spraying. Poor atmospheric conditions often are the cause of mission cancellations. For example, in 1998 and 1999, spraying took place on 125 days of the year. During the other 240 days the spray planes were grounded, with the majority of cancellations due to bad weather (U.S. State Department, 2002).

3 Data sources

3.1 Data on illicit crops

Our dataset contains information on the amount of land used to grow coca bushes by municipality and year over the period 1999-2005. The number of coca acres is calculated by the Integrated Monitoring System of Illicit Crops (SIMCI by its Spanish acronym) of the United Nations Office on Drugs and Crime (UNODC). SIMCI is a satellite-based monitoring system that estimates the extension of coca crops annually since 1999. It uses satellite imagery of the entire territory of Colombia's mainland (roughly 282 million acres). In addition to geo-referencing the satellite pictures and to the visual interpretation of coca fields, the estimation process involves verification flights and corrections due to potential confounders of the crop estimate, like the presence of clouds or crop eradication taking place before the estimate cut-off date on December 31st (UNODC, 2007).

Provided by the National Drug Enforcement Office (DNE by its Spanish acronym), we also have municipal-level data on the number of acres of illicit crops sprayed by Colombian authorities.[7] The dataset lists every eradication event including the date of occurrence, the exact location, and the area sprayed. The data covers over 10,000 spraying events in the period 1999-2005. We observe all this information.

3.2 Data on conflict

Conflict-related variables come from an event-based conflict dataset on Colombia. For every event the dataset records its type, the date, location, perpetrator, and victims involved in the incident. The dataset is described thoroughly by Restrepo et al. (2004), and has been previously used by Dube and Vargas (2013). Here we provide a succinct account of the data collection process.

The dataset is built on the basis of events published by CINEP, a local NGO that monitors political violence. Most of the event information comes from two primary sources: The Catholic Church, which has representation in almost every municipality in Colombia–and over 25 newspapers with national and local coverage. The inclusion of reports from Catholic

[7]Eradication can occur either through aerial spraying or manually, depending on the nature of the economic exploitation of the fields: While large-scale plots are sprayed, smaller plots are rooted out manually. We study aerial spraying here because during our sample period manual eradication figures are negligible compared to aerial spraying. Including manual eradication, however, does not change our basic results.

priests, who are often located in rural areas that are unlikely to receive press coverage, greatly broadens the municipality-level representation. Based on these sources, the resulting data includes every municipality that has ever experienced a conflict related action (either a unilateral attack or a clash between two groups).

In our analysis we employ several outcomes related to the dynamics Colombia's armed conflict. These are clashes between insurgent groups and government forces, attacks by left-wing guerrillas, and civilian and combatant casualties resulting from clashes or attacks.

3.3 Other components of Plan Colombia

Recall that the PC strategy against coca crop cultivation includes, in addition to the eradication of illicit crops, initiatives for substituting coca with alternative crops as well as the expansion of the military capacity of the army. A common objective of both these complementary initiatives is to increase what could be called "state presence" in areas previously controlled by drug traffickers or rebel organizations. In order to identify the effect of aerial eradication we control for these additional components of PC.

First, from government's agency *Acción Social*, we have the municipal-specific area engaged in government-backed projects of illegal-crop substitution. *Acción Social* channels resources from both Colombia and foreign aid (particularly from USAID) to promote alternative crops among rural farmers known to have been involved in growing illegal crops. The raw data contains information on the number of crop-substitution projects as well as details on the timing of their execution, the plots involved and their size. This allows us to measure municipal-level project intensity (in terms of the area covered as a proportion of the total area of the town) by year.[8]

Second, using data compiled from the website of the Colombian army and press archives, we construct an indicator of the presence of army mobile brigades by municipality and year. Then, using GIS techniques, we construct for each municipality the orthodromic distance to the closest brigade on a yearly basis.[9] The inverse of such measure is a proxy of the presence of state security forces.

[8]When plots covered within a project extend over more than one municipality we impute land shares according to the proportion of the total land of each municipality involved in the aggregate area of all the municipalities included. In addition, since single projects are set to be implemented during several years we assign to the first year the total project-covered area weighted by the inverse of the entire duration of the project, and thereafter the same share year-by-year in a cumulative way.

[9]The orthodromic distance is the shortest distance between any two points on a surface of a sphere measured along a path on the surface of the sphere, as opposed of going through the sphere's interior. Results are however robust to using the latter (Euclidean distance).

3.4 Rainfall

We control for precipitation levels in all specifications. We use the Tropical Rainfall Measuring Mission (TRMM) database on near-real-time tropical rainfall estimates. The TRMM is a joint project between NASA and the Japan Aerospace Exploration Agency (JAXA). The estimates are provided on a $0.25° \times 0.25°$ grid over the latitude band 50° North-South so we matched the available rainfall estimates with the coordinates of each municipality.

4 Long-term analysis

4.1 Empirical strategy

We use annual data to study the long-term effect of the eradication program on the area cultivated with illegal coca crops and on conflict-specific outcomes. To assess the impact on coca crops we estimate the following model:

$$y_{it} = \alpha y_{it-1} + \delta Eradication_{it} + \beta_i + \beta_t + \gamma' X_{it} + \varepsilon_{it} \tag{1}$$

where y_{it} represents the amount of land cultivated with illicit crops in municipality i and year t, and $Eradication_{it}$ is number of hectares (ha) of coca crops eradicated through aerial spraying in municipality i and year t.[10] By including the lagged value of the outcome, y_{it-1}, we take into account the persistence of coca fields. X_{it} is a vector that includes the area involved in crop-substitution programs, the distance to the nearest base of an army's mobile brigade and average rainfall levels.[11] We also include both municipality (β_i), and year (β_t) fixed effects to capture both time-invariant municipal-specific characteristics or aggregate annual shocks that may confound the estimates of interest. The term ε_{it} represents municipality-specific yearly shocks, and are allowed to be correlated across time for the same municipality in all regressions.

We are also interested in the long-term effect of eradication efforts on the dynamics of the local conflict. We look at this by estimating:

$$y_{it} = \beta_i \exp\left(\delta Eradication_{it} + \lambda t + \gamma' X_{it} + \varepsilon_{it}\right) \tag{2}$$

where y_{it} represents either guerrilla attacks, civilian casualties, combatant casualties, or clashes between government forces and left-wing guerrilla groups; X_{it} is the same as in

[10] One hectare is about 2.47 acres.

[11] Because new brigades were created throughout our period of analysis, the distance to the closest base is time-varying and so this control is not collinear with the municipal fixed effect.

equation (1); λt is a linear time trend and β_i a municipality specific fixed effect. Because of the count nature of the outcomes we adopt a nonlinear specification to our model (Cameron and Trivedi, 2005, pp. 802-808).

4.2 Long-term results

4.2.1 Impact on coca cultivation

Figure 1 shows the distribution of coca fields across municipalities in 1999 (Figure 1a) and 2005 (Figure 1b), respectively the first and last year of our sample. The grey scale uses the same intensity cutoffs in both years, namely the quartiles of the distribution of coca crops in the initial year (1999). This is done for comparison purposes. It allows us to show the inter-period change in the location and intensity of coca fields.[12] Darker municipalities correspond to a higher coca intensity relative to the municipality area.[13] In the initial sample year (1999) coca was present in 89 municipalities and the mean acreage of coca conditional on having a positive amount was 1,845 ha. In contrast in 2005 coca had doubled its municipal presence reaching 190 towns, albeit with a much lower average field extension (451 ha) which suggests a secular atomization of the production. Indeed, keeping the same intensity quartiles of Figure 1a, Figure 1b shows a much more sparse coca production, but with a lower incidence of dark colors.

When we normalize coca cultivated areas by the total municipality area in thousands of ha, we find that, on average, each municipality in Colombia has 1.05 ha of coca for every thousand ha of land (Table 1). However, if the sample is restricted to the municipality/years that register positive cultivated areas (1,170 observations distributed across 275 out of 1,117 Colombian municipalities), the mean jumps to 4 ha of coca for every thousand ha of land. The standard deviation is about ten times the mean, evidencing the large variation that there is in the size of coca crops across coca growing municipalities.[14]

Figure 2 presents the geographic distribution of the coca spraying program in 1999 and 2005, with quartiles of spraying intensity measured in 1999. Darker municipalities are places more intensively sprayed. 27 municipalities witnessed spraying in 1999. The mean sprayed

[12] This practice is repeated in all the subsequent figures, that map all the variables of interest in the first and the last years of our sample.

[13] In the case of the percentage of the municipal area cultivated with coca, the first (lower intensity) quartile (lightest gray) goes from 0.03 to 1.04 ha of coca for every thousand ha of land; the second quartile (somewhat darker gray) goes from 1.04 to 2.73 ha of coca for every thousand ha of land; the third quartile (dark gray) from 2.73 to 6.77 and the fourth (highest intensity) quartile (black) from 6.77 to 314.94. This means that in 1999 the municipality with the highest intensity of coca production devoted almost a third of its land to growing coca.

[14] We computed the total area of the municipalities from the Colombia GIS datasets provided by IGAC, the country's official geography and cartography bureau.

area conditional on a positive value of spraying was 1,597 ha. In 2005 the program was expanded to 111 municipalities, and the mean eradicated area was 1,250 ha. Figure 2 reveals that the intensity of the eradication campaign (share of municipal surface that experienced coca spraying) increased significantly from 1999 to 2005.[15] The mean area sprayed per municipality/year is 1.01 ha per thousand ha of land (Table 1). This figure is larger than the mean coca land because the same plot of land can be (and in fact it is often) sprayed many times during the same year (Nivia, 2001). While there is no data on the amount of times the same plot is sprayed, on a more aggregate level there are about eight coca aerial spraying events per municipality/year on average for municipalities with positive eradications.

We then estimate the effectiveness of the aerial spraying on coca growing, which is the outcome that should be directly affected by eradication efforts. To this end we estimate equation (1) as a linear dynamic panel, using the Arellano-Bond (1991) estimator. Table 2 reports the results of the effect of the aerial spraying of coca fields on the area cultivated with the illicit crop at the municipal level. The benchmark specification, which in addition to the municipality and year fixed effects controls for the lagged coca cultivation, is reported in column 1. Other controls are included additively in the subsequent columns. Column 2 adds rainfall levels to control for climatic conditions that may affect both the incidence of crops and the aerial eradication efforts. Column 3 adds further the municipal-level area affected by government-led crop substitution program. This is an important potential confounder because the crop-substitution efforts are intended to make the growers of illicit crops to voluntarily substitute these for legal crops, with the technical and financial support from the government. The last column adds a variable that measures the distance to the closest base of a mobile military brigade. These military units, the firsts of which were created in the late 1990s, are supposed to perform timely deployments and complicated tactic maneuvers to increase the military control in areas with known presence of illegal armed groups. The bulk of the mobile brigades was created during the Uribe administration (2002-2010) when the size of the military increased from 260 thousand to about 450 thousand (Florez, 2011). Indeed, because mobile brigades with different jurisdictions where introduced in Colombia at different points in time, this specification can also be estimated including fixed effects.

The estimated coefficient of the impact of the aerial eradication efforts on the area cultivated with coca is very similar across the four specification and in all cases it is significant at the 5 percent level.[16] Table 2 suggests that on average, during our period of analysis, the

[15]Note that the comparison of Figures 1a and 2a, and 1b and 2b, implies that in a few instances there appear to be eradication efforts in areas where coca is not present. This is explained by the fact that the satellite images of coca fields are captured at the end of each calendar year, while the spraying figures are the cumulative sprayed areas over each municipality across the entire year.

[16]In Table 2 neither rainfall (column 2) nor any of the controls of the other components of PC (columns

marginal acre of illicit coca crops sprayed reduced the cultivated area in 11 percent of an acre. This figure is however likely to underestimate the mean effect of the spraying campaign since multiple eradication episodes may have occurred on the same coca field.

Table 4 reports the results coming form a specification similar to the one reported in Table 2, but where municipalities are conditioned on having had a positive amount of coca in the 1999 satellite snapshot (the first year of our sample, and the first year in which coca land in Colombia is measured by SIMCI/UNODC). This strategy allows us to investigate the robustness of our estimates of the effect of aerial spraying on coca cultivation using a specification that is much less zero-inflated. As shown in Table 5, 89 municipalities were identified as having coca in 1999. By the end of the of the period coca persisted in 81 of those (91 percent).

According to Table 4, each acre of coca sprayed in the municipalities that presented the illicit crop in 1999 reduced the cultivated area in 15 percent of an acre. Again, the coefficient is robust in magnitude and significant (this time at the 1 percent level) to the additive inclusion of the controls described for the last table.

It is worth highlighting that due to data availability our estimates should be interpreted as local effects. Indeed, in this paper we do not take into account neither the multiple spraying that mat take place on the same fields, nor potential general equilibrium effects like the fact that the eradication that takes place in one municipality can make coca growers move their illegal crops to neighboring municipalities. Our results are however consistent with accounts that suggest that the illegal crop eradication initiative has been relatively ineffective, mainly due to the fast recovery of coca fields after eradication efforts. (e.g. GAO, 2008 and Mejía and Restrepo, 2010).

The literature suggests three broad potential explanations for this phenomenon. First, coca is often replanted on sprayed fields, and unless these are repeatedly sprayed, bushes can provide up to four harvests a year depending on the plant variety, its age and the ecological conditions of the field (Mejía and Rico, 2010). In addition, coca farmers prune the plants after spraying, cultivate areas where plants are harder to localize and spray (such as under dense foliage), and intersperse coca plants with legal crops (Felbab-Brown, 2010). Second, eradication campaigns also drive the illicit crops into remoter regions, and induce a shift to smaller-scale plots. Third, the productivity of coca bushes may have increased overtime in terms of the capacity to transform the coca leaf into cocaine base (Mejía and Restrepo, 2010). These three phenomena constitute an obstacle to eradication, especially to aerial spraying by increasing its costs and reducing its effectiveness.

The variety of potential reasons explaining the lack of effectiveness of the eradication

3 and 4) is significant at conventional statistical levels.

efforts imply significantly different policy responses. It is then important to try to asses their relative salience. Table 4 provides evidence supporting the first mechanism. Estimated coefficients in this table tell us to what extent the regions in which coca was present at the start of PC experienced successful eradication. While the effect is larger than the baseline 11 percent (Table 2), it is not so by a large proportion. In addition, Figure 2 provides visual evidence in favor of the second mechanism too, as it shows a substantial geographical atomization of coca during our period of analysis. Coca fields doubled from 89 municipalities in 1999 (Figure 1a) to 190 in 2005 (Figure 1b), and the average crop size decreased four times from 1,845 ha in the first year to 451 in the last. Hence, in addition to the crops being replanted on the same municipalities in which eradication takes place (either on the same fields or in more frontier areas of the town), coca fields also witnessed a large atomization. In contrast, using various rounds of a representative survey of coca growers, which among other things asks about coca yields, Rozo (2012) finds no evidence supporting the third mechanism, namely an increase in the productivity of caca leaves in the production of cocaine base.

That coca grows again on sprayed fields or the surrounding areas is consistent with a lack of government-led consolidation efforts to take full control of regions in which illicit crops are eradicated. Indeed, the lack of short-term security and long-term institutional consolidation initiatives in the territories gained to the rebels and where eradication took place is the main objection of the current administration to the *Democratic Security Policy* promoted by president Uribe (2002-2010).[17] We will come back to this hypothesis when discussing the short-term results in the next section.

4.2.2 Impact on conflict outcomes

The eradication of illegal crops reduces the raw material of the primary source of finance of insurgent groups in Colombia. In turn this may have two opposite but simultaneous effects. On the one hand the lack of sufficient funding may induce armed groups to retract and slow down their activities. On the other hand armed groups have an incentive not to give up the control of coca regions to the government. At least without disputing them violently.

This simple analytical framework, which is consistent with an illegal group having a national political agenda and a local financial enterprise, predicts that in spite of the eradication-induced negative shock to the income of the illegal armed groups, which in fact may lead to an overall decrease of their armed activity throughout the country, localized violence in the eradicated areas may increase. Our empirical analysis in this section provides evidence that eradication efforts lead to an increase of violence at the local level. Thus we highlight

[17] Interview with Álvaro Balcázar, director of the government's Administrative Unit of Consolidation (UACT, from the Spanish acronym), October 3rd, 2011.

an unintended negative consequence of PC in terms of on of the Program's main objectives, namely the reduction of violence in Colombia.

Figure 3 presents the geographic distribution of guerrilla attacks in 1999 and 2005. The mean of guerrilla attacks is 0.3 for every 10,000 people per municipality/year (Table 1).[18] However, the number of municipalities that receive a guerrilla attack decreased from 294 in 1999 to 158 in 2005. Similarly, the maximum number of attacks witnessed by the same town decreased 18 at the beginning of the period to 10 in 2005. Figure 3 suggests that the reduction in the intensity of attacks is mainly driven by a significant drop of the guerrilla activity in the north-east of the country.

Figure 4 maps the incidence of clashes between government forces and guerrilla groups. The total number of clashes decreased from 211 in 1999 (Figure 4a) to 160 in 2005 (Figure 4b). In addition to more geographically concentrated, clashes became more intense during this period: The maximum number of clashes per municipality/year rose from 6 in 1999 to 10 in 2005. According to Figure 4, the hot spot of clashes that appears in the north-east of the country in 1999 disappeared by 2005. Instead, spots of intense clashing emerged in the center and south of the country. However other areas persisted in terms of clashes between government forces and guerrillas, specifically the north-west of the country.

About six times more combatants than civilians died as a direct result of the conflict during the period of analysis. The mean total number of civilian casualties is 0.09 and that of combatants is 0.57 for every 10,000 people per municipality/year (Table 1). Figures 5 and 6 show respectively the spatial distribution of incidence of combatant and casualties in conflict events involving the guerrillas (i.e. guerrilla attacks or clashes with the guerrillas) across Colombian municipalities in 1999 and 2005. The figures show that both combatants and civilians experienced a large improvement in their security over this period.

Our second set of results then estimate the impact of aerial spraying on the incidence of conflict-specific violence, as measured by the outcomes already described. Given the count nature of the dependent variables, and in order to take care of the potential endogeneity of coca eradication, we do this by estimating equation (2) using the Wooldridge (1997) estimator, that fits an exponential specification that allows for multiplicative fixed effects.[19] Table 6 reports the long term impact of coca eradication efforts on measures of conflict-specific outcomes. There is one column for each outcome and all specifications include the full set of controls (municipality fixed effects, linear time trends, the presence of the alternative

[18]The average population across municipalities is roughly 40,000 which means that on average each Colombian municipality suffers about 1 violent attack *every year*.

[19]Because we lack a similarly convincing identification strategy, we do not test the effect of eradication on the country's aggregate level of violence.

crops program and the distance to the closest mobile military brigade).[20] Panel A reports the marginal effects, which should be interpreted as the impact of one additional acre of coca sprayed on the percentage change of the dependent variable. In turn, coefficients in Panel B should be interpreted as the impact of the mean area sprayed on the conflict-specific outcome.[21]

According to column 1 of Table 6, one additional acre of coca sprayed leads to nearly 0.010 percent additional guerrilla attacks (Panel A, significant at the 1 percent level). Though this effect may seem small, taking into account the scope of the spraying campaign changes the picture. A municipality that faces the mean spraying witnesses and increase of guerrilla attacks of over 20 percent (Panel B). Hence the economic magnitude is quite substantial.

The armed initiative of the guerrilla in Colombia is obviously not uncontested (or at least it should not be). As reported in column 2 of Table 6, one extra acre of coca sprayed leads to 0.014 percent additional clashes between the guerrilla and the government (Panel A, significant at the 1 percent level). This is consistent with the contestation story summarized in the conceptual framework at the beginning of this subsection, and further suggested by the positive and significant result on unilateral guerrilla attacks reported in column 1: When the guerrilla tries to recover the coca-growing areas they face the government forces, which try to hold the upsurge of guerrilla attacks. Again, the seemingly small figure is not so much if one takes into account the mean sprayed coca area. A municipality that faces the mean eradication experiences almost 29 percent more clashes between the guerrilla and the government forces (Panel B).

The result that coca eradication has increased guerilla attacks in municipalities where eradication took place instead of weakening their military power via a reduction in coca income is consistent with the idea that instead of running away to non-coca-growing (and therefore not exposed to spraying) municipalities, guerrillas do not easily cede the control of coca-growing municipalities. According to Felbab-Brown (2010, Chapter 4), fighting eradications efforts is helps the guerrilla gain the support and allegiance of local coca farmers.[22]

One way of fighting eradication is by shooting spraying aircrafts. Up to the year 2007, 1,116 spraying aircraft had been impacted by gun fire (Revista Semana, 2007). A likely consequence of these shootings and the clashes mentioned above, is surely the death of

[20] In this specification, contemporaneous and lagged rainfall levels are used to instrument municipal eradication.

[21] Since the majority of the country's municipalities did not witness coca crops during our period of analysis and hence were never fumigated, the mean area sprayed is computed conditioning on municipalities having experienced at least one eradication event. Hence, we focus on the average spraying on places that were actually fumigated

[22] Although the results is also consistent with anecdotal evidence linking guerillas' adaptation to eradication by switching to kidnapping and extortion in their areas of influence.

combatants from both the government forces and the rebels. In column 3 of Table 6 we look specifically at this outcome and estimate a positive and significant effect that suggest that one additional acre of coca sprayed increases the death of combatants in 0.01 percent (Panel A). Most importantly, a municipality that gets the average aerial spraying of coca fields experiences a non-negligible 24 percent increase in the number of combatants killed (Panel B).

In turn, the results suggest that an excess civilian casualties does not result in the long term from the aerial spraying of coca fields. This contrasts with the short-term estimates that we present next.

5 Short-term analysis

5.1 Empirical strategy

In this section we focus primarily on the effect of illicit crops eradication efforts on short term violence outcomes, using daily frequency data at the municipal level.[23] The events of interest in our study are each of the aerial fumigations of coca fields that are carried out in Colombia during our sample period, 1999-2005. We define the "event window" as the period over which the violence outcomes are observed around each spraying event. Using daily data, in order to capture the short-term violence dynamics both *pre* and *post* each event, our benchmark event window spans for a month (30 days) both before and after every event.[24] The pre-event window is meant to capture previous conflict dynamics, which are of interest because military forces are generally scheduled to arrive to the areas to be sprayed several days in advance in order to secure the places.[25] The post-event window, instead, will capture the short-term violent reaction to the spaying events.

We estimate the model:

$$y_{it} = \beta_i \exp\left(\gamma PRE_t + \alpha POST_t + \delta_{rt} + \varepsilon_{it}\right) \tag{3}$$

where y_{it} represents each of the violence variables in municipality i recorded on day t. PRE_t is a time indicator that captures the window spanning for 30 days before the eradication event. That is, γ captures the effect of the eradication on the incidence of violent outcomes prior to it taking place. We include this term in order to control for previous conflict dynamics that may affect where and when current fumigation efforts are going to be implemented. We

[23]We cannot assess the short term effect of the aerial eradication campaign on the size of coca plots because the satellite-based measures of the presence of coca crops are only available annually.

[24]Rarely two or more eradication events occur in the same municipality one shortly after the other.

[25]Ministry of Defense, 2009 (interview with Eradication Policy Advisor).

include the time indicator $POST_t$, spanning for 30 days after the eradication event. That is, α is our main coefficient of interest as it captures the violent reaction of the eradication event. We include municipality fixed effects (β_i) to capture time invariant municipal-specific characteristics that may be related to conflict and eradication variables, such as geographic variables (Abadie, 2006). We also include 6 regions $\times$ 84 months = 504 region$\times$month dummy variables, represented by δ_{rt}, that capture the effect of time shocks that are common to all the municipalities located within the same geographical region.[26]

Because of the count nature of the outcome, in equation (1) we adopt an exponential model (Cameron and Trivedi, 2005, pp. 802-808).

5.2 Short term results

Table 7 reports the marginal effects in percentage terms of the estimated coefficients. On average, we do not find significant changes in any of the outcomes in the month before the spraying events. In contrast, shortly after the occurrence of the events civilian casualties present a significant 72 percent increase (column 2). In turn this seems to be the result of an increase in guerrilla attacks in the month after an aerial eradication event. Guerilla attacks increase roughly 20 percent in the $POST$ window (p-value=0.11).

In column 3, we do not find significant effects of the coca spraying events on clashes between the government forces and the guerrillas. Consistent with this, in column 4 we do not find a significant increase in combatant casualties.

These results are consistent with the conceptual framework in which eradication efforts induce contestation from the illegal groups in charge, in an effort to fight for the control of resources that are key to finance their survival.[27] However, in contrast with the long-term results, the short-term guerrilla upsurge following eradication efforts is not contested by the government as clashes are not significantly different from zero. This is consistent with the hypothesis that short-term eradication efforts at the dawn of PC were largely unaccompanied by military presence for consolidation purposes, something that the current government (2010-2014) has explicitly addressed.[28]

[26] The six geographical regions are clusters of states which are commonly used in Colombia for public policy and planning objectives.

[27] It has been shown in the context of the Colombian conflict that civilians are targeted by armed when there is competition for territorial control (Vargas, 2009).

[28] Interview with Álvaro Balcázar, director of the government's Administrative Unit of Consolidation (UACT, from the Spanish acronym), October 3, 2011.

6 Conclusion

In this paper we conduct for the first time a rigorous econometric evaluation of Plan Colombia, the largest aid package ever received by a country in the western hemisphere. While Plan Colombia has been the subject of continuous debate, criticism and praise has come mostly from NGOs and journalistic accounts, while evidence-based arguments are usually absent. Indeed, after over a decade of its existence, surprisingly there has been very little academic research on whether PC has been effective or not in achieving its goals, or what elements of it could be improved.

We assess both the short- and the long-term effect of PC in terms of the two outcomes the package intended to affect: The production of coca and the dynamics of the Colombian armed conflict. We do so by focusing on one particular and well defined policy instrument: the eradication of illegal-crop fields. We investigate the long-term effect of eradication on coca production and a large set of conflict-related violence outcomes controlling for various state presence measures as well as climate conditions, municipality and time fixed effects and linear time-trends.

Our preferred estimate suggests that one additional acre of coca eradicated reduces the cultivated area by about 11 percent of an acre on the margin. The mean effect of the eradication effort on coca crops is however plausibly larger as there is evidence that the same coca fields are often sprayed multiple times. However, as the available data on aerial spraying is aggregated at the municipal level and it is not geo-referenced, it is impossible to know for certain the average number of episodes the same field is sprayed. Hence, we are only able to report the marginal effect which is most likely a lower bound of the mean effect of the eradication program on the size of coca crops.

In terms of the effect of the aerial spraying program on violence our estimates indicate that both in the short and the long run, guerrilla activity increases in sprayed areas. In addition, while in the short run this results in significantly higher numbers of civilian casualties, in the long run guerrilla attacks are challenged by government forces which increases two-sided clashes and the killing of combatants. These results are consistent with the hypothesis that while coca eradication weakens the guerrilla by cutting one of its main source of finance, it is not enough to decrease localized violence as the guerrilla tries to hold on to control of the coca fields.

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Table 1: Descriptive statistics

	1999		2005			
	Mean	St. Dev.	Mean	St. Dev.	Obs.	Source
Illicit crops measures						
Coca crops (per 1K ha)	1.05	11.86	0.36	1.61	7,819	SIMCI/UNODC
Sprayed area (per 1K ha)	0.69	10.01	0.95	5.84	7,819	DNE
Conflict Measures[b]						
Clash gov.-guer. (per 10K peop.)	0.20	0.84	0.12	0.44	7,595	CERAC
Guer. attacks (per 10K peop.)	0.33	1.03	0.10	0.40	7,595	CERAC
Civ. casualties (per 10K peop.)	0.13	0.90	0.03	0.26	7,595	CERAC
Comb. casualties (per 10K peop.)	0.52	2.84	0.24	1.46	7,595	CERAC
Institutional controls						
Land crops sub. (per 1K ha)	0.08	0.78	7.39	36.18	7,819	Acción Social
Dist. to mil. base (Km)	391.61	204.29	160.52	90.91	7,854	Army and press
Rainfall						
Rainfall (mm)	158.11	53.38	123.34	49.60	7,770	TRMM/NASA

Table 2: Effect of aerial coca spraying on coca area (long term)

Dependent variable: Share of coca cultivated area	(1)	(2)	(3)	(4)
Eradicated area	-.114**	-.116**	-.118**	-.121**
	(.053)	(.051)	(.057)	(.051)
Controls				
Lag. Cultivated area	.698***	.700***	.704***	.705***
	(.057)	(.056)	(.060)	(.058)
Rain		.110	-.026	-.019
		(.113)	(.078)	(.035)
Crops substitution			-.002	-.002
			(0.010)	(.005)
Dist. military base				.004
				(0.014)
Observations	5,595	5,540	5,540	5,540
Number of municip.	1,119	1,108	1,108	1,108

Notes: Regressors not shown include municipality and year fixed effects. Robust standard errors are in parentheses. Instruments are lags from 2 on back (until 1999) of the coca cultivated area, lags from 1 on back (until 1999) of the policy variables (eradication, crop substitution and distance to closest military base) and the first difference of rain. *** is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level..

Table 3: Effect of aerial coca spraying on coca area (long term) − Robustness

Dependent variable: Share of coca cultivated area	Agg. lin. trend		Stat. lin. trend		Reg. lin. trend.	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: *Baseline*						
Eradicated area	-.115**	-.121**	-.114**	-.115**	-.115**	-.117**
	(.051)	(.050)	(.056)	(.057)	(.048)	(.051)
Observations	5,595	5,540	5,595	5,540	5,575	5,520
Municipalities	1,119	1,108	1,119	1,108	1,115	1,104
Panel B: *Normalized area*						
Eradicated area	-.064	-.069	-.063	-.067	-.063	-.066
	(.051)	(.050)	(.052)	(.050)	(.052)	(.052)
Observations	5,585	5,540	5,585	5,540	5,565	5,520
Municipalities	1,117	1,108	1,117	1,108	1,113	1,104
Controls						
Lag. Cultivated area		✓		✓		✓
Rain		✓		✓		✓
Crops substitution		✓		✓		✓
Dist. military base		✓		✓		✓

Notes: Regressors not shown include municipality fixed effects. Robust standard errors are in parentheses. Instruments are lags from 2 on back (until 1999) of the coca cultivated area, lags from 1 on back (until 1999) of the policy variables (eradication, crop substitution and distance to closest military base) and the first difference of rain. *** is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level.

Table 4: Effect of aerial coca spraying on coca area for 1999 coca municipalities (long term)

Dependent variable: Share of coca cultivated area	(1)	(2)	(3)	(4)
Eradicated area	-0.148***	-0.151***	-0.152***	-0.153***
	(0.0523)	(0.0497)	(0.0470)	(0.0468)
Controls				
Lag. Cultivated area	0.703***	0.713***	0.700***	0.689***
	(0.0727)	(0.0644)	(0.0655)	(0.0698)
Rain		3.189	3.156	1.537
		(2.491)	(2.559)	(2.538)
Crops substitution			-0.500	-0.580
			(0.483)	(0.534)
Dist. military base				-0.730
				(0.913)
Observations	445	445	445	445
Number of municip.	89	89	89	89

Notes: Regressors not shown include municipality and year fixed effects. Robust standard errors are in parentheses. Instruments are lags from 2 on back (until 1999) of the coca cultivated area, lags from 1 on back (until 1999) of the policy variables (eradication, crop substitution and distance to closest military base) and the first difference of rain. *** is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level..

Table 5: Municipalities with coca presence
1999 and 2005

		2005		
		No	Yes	**Total**
1999	No	920	108	**1,028**
	Yes	8	81	**89**
	Total	**928**	**189**	**1,117**

Source: SIMCI/UNODC

Table 6: Effect of aerial coca spraying on conflict violence (long term)

Dep variable:	Guerrilla attacks (1)	Clashes gov.-guer (2)	Combatant casualt. (3)	Civilian casualt (4)
Panel A: Marginal effect of eradicated area				
	0.00989***	0.0138***	0.0116***	-0.00228
	(0.00316)	(0.00354)	(0.00404)	(0.0144)
Panel B: Implied mean effect				
	20.44***	28.58***	23.88***	-4.716
	(6.535)	(7.308)	(8.350)	(29.81)
Observations	5,540	5,540	5,540	5,540
N. of municip.	1,108	1,108	1,108	1,108

Notes: Regressors not shown include a linear trend, the share of area with crops substitution, the distance to the closes base of a military mobile brigade, and municipality fixed effects. Instruments for Eradicated area are rain and lagged rain. Panel A reports marginal effects, which should be interpreted as the impact of one additional acre of coca sprayed on the percentage change of the dependent variable. Coefficients in Panel B should be interpreted as the impact of the mean area sprayed (conditional on at least one spraying episode taking place) on the dependent variable. Clustered standard errors by municipality are in parentheses. *** is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level.

Table 7: Effect of aerial coca spraying on conflict violence, percentage change (short term)

Dep variable:	Guerrilla attacks (1)	Clashes gov.-guer (2)	Combatant casualt. (3)	Civilian casualt (4)
Pre-event window	11.49	7.38	18.06	5.68
	(12.36)	(11.75)	(12.91)	(29.39)
Post-event window	19.40	8.25	10.50	72.00***
	(12.23)	(11.82)	(13.20)	(27.78)
Observations	1,636,480	1,585,340	1,444,705	692,947
N. of municip.	640	620	565	271

Notes: Regressors not shown include municipality and region-year fixed effects, where region is a cluster of neighboring departaments. Standard errors are in parentheses. *** is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level.

Figure 1: Spatial distribution and intensity of coca crops across Colombian municipalities: 1999 and 2005

Figure 1a: Coca intensity 1999

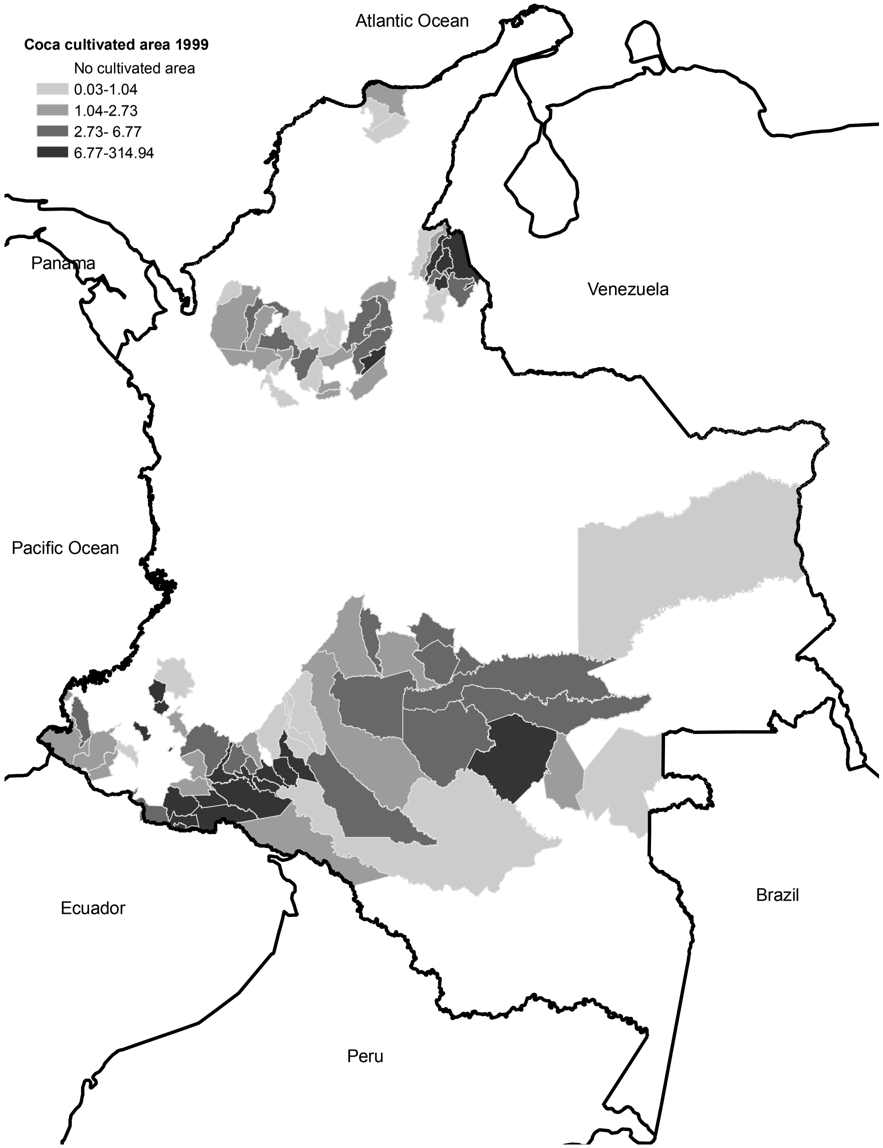
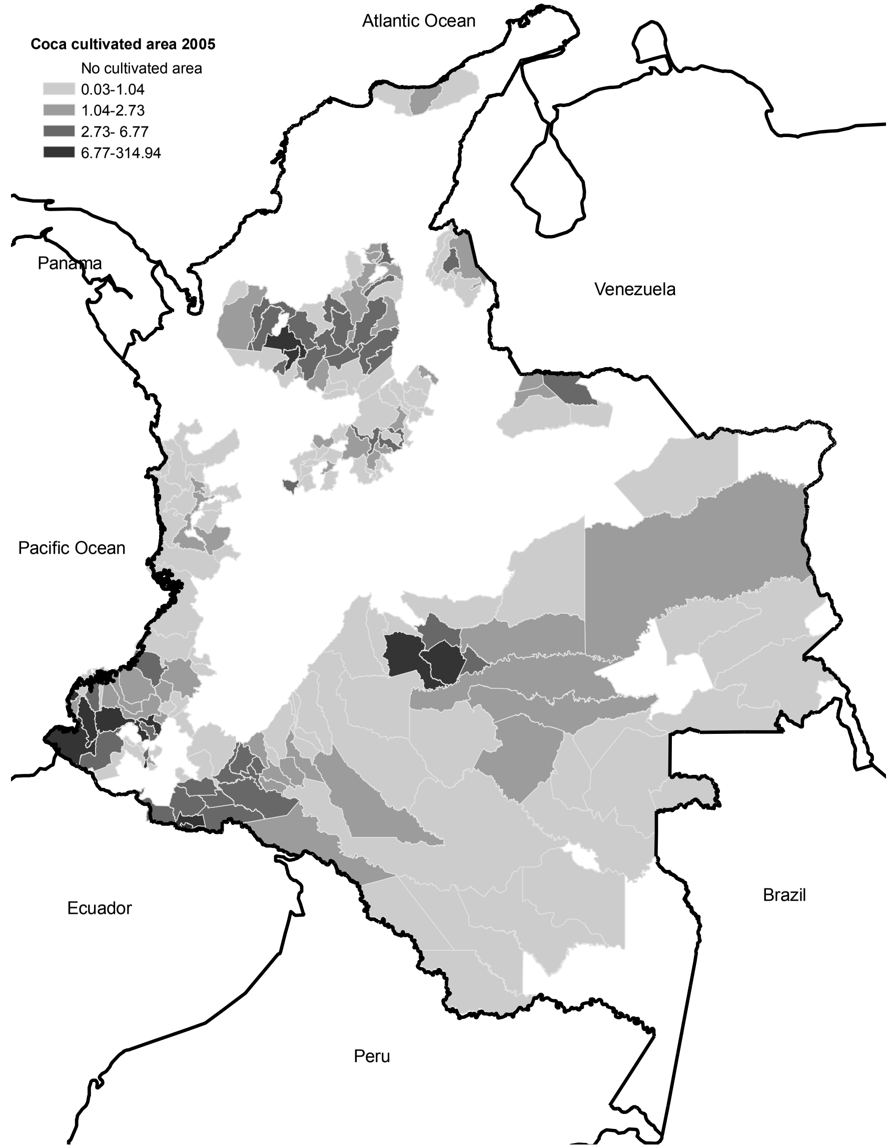


Figure 1b: Coca intensity 2005



Notes. This figure shows coca intensity in Colombian municipalities in 1999 and 2005. Coca intensity is measured as the land used for cultivating coca (in thousands of hectares). *Sources*: Shape file from IGAC; data on coca crops from SIMCI/UNODC (see data appendix for details).

Figure 2: Spatial distribution and intensity of aerial spraying of coca crops across Colombian municipalities: 1999 and 2005

Figure 2a: Aerial spraying 1999

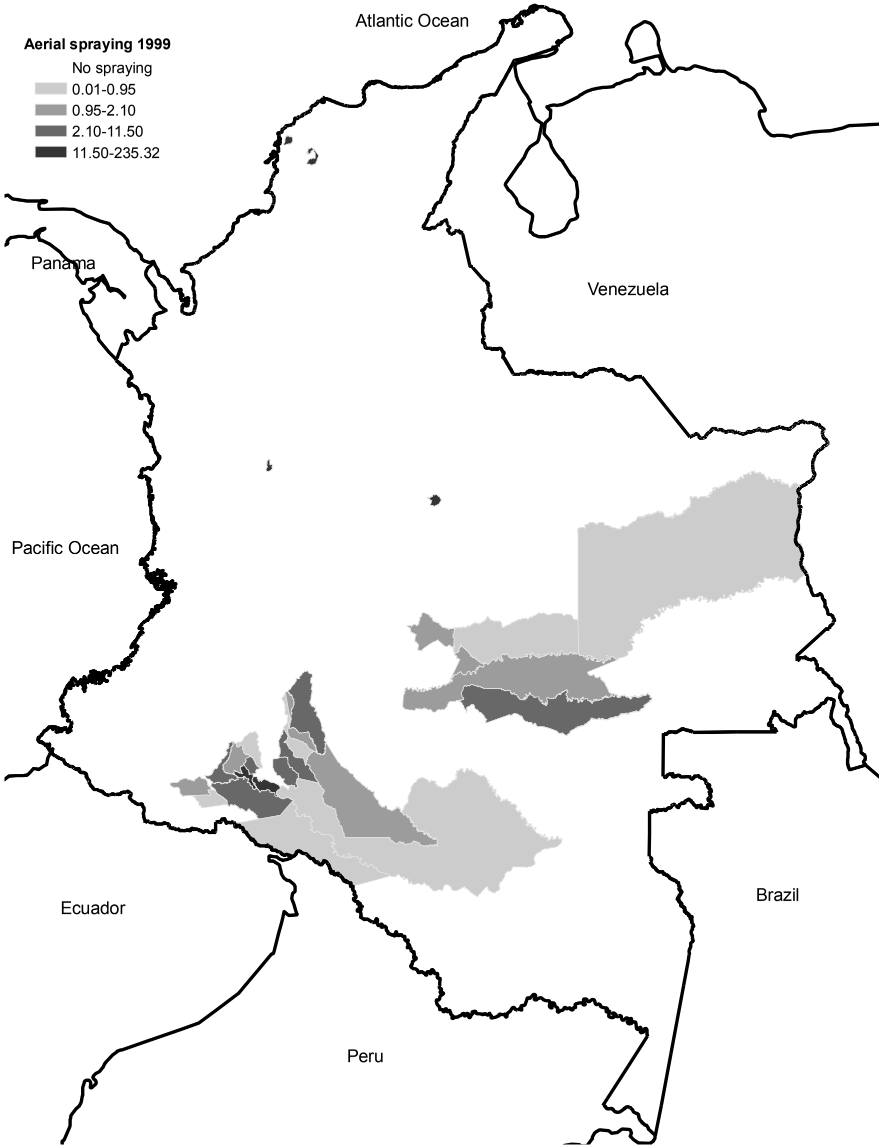
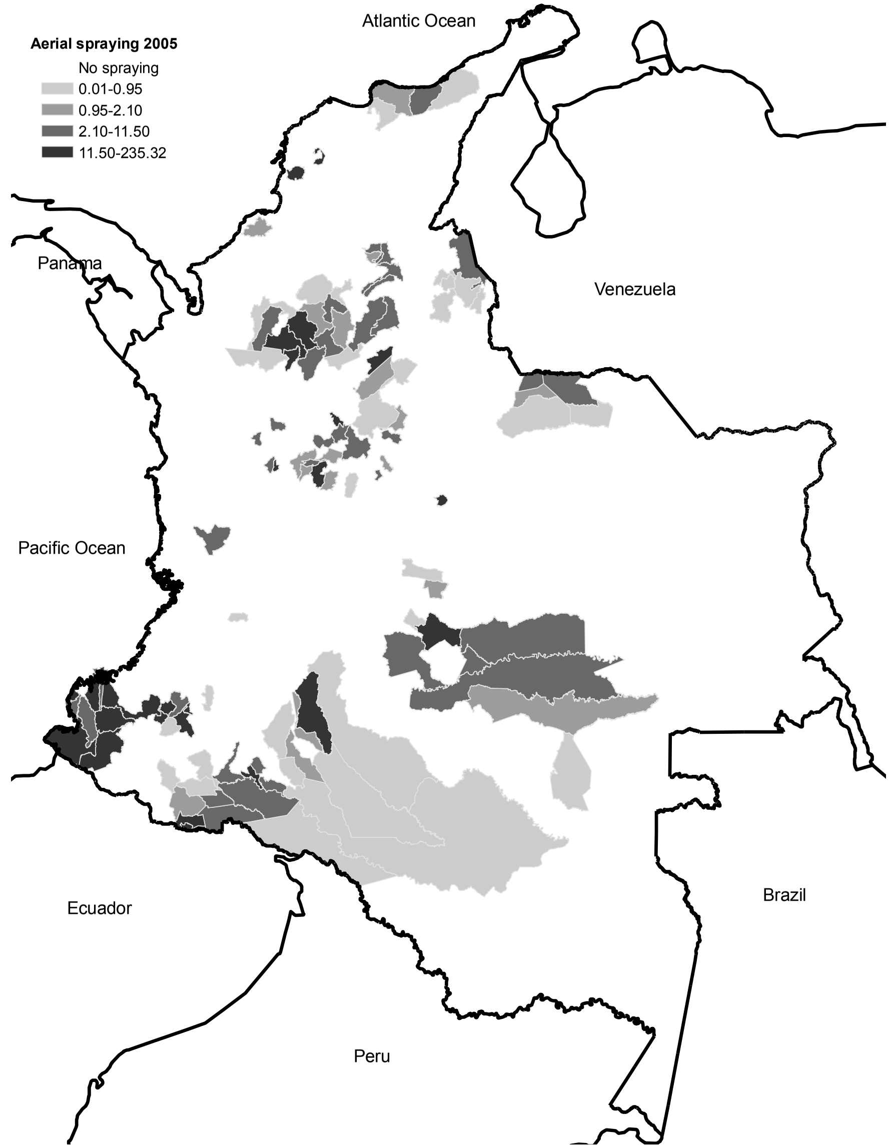


Figure 2b: Aerial spraying 2005



Notes. This figure shows the intensity of the spraying of coca crops in Colombian municipalities in 1999 and 2005. This is measured as the the area of coca fields sprayed from airplanes (in thousands of hectares). *Sources*: Shape file from IGAC; coca spraying from DNE (see data appendix for details).

Figure 3: Spatial distribution and intensity of guerrilla attacks across Colombian municipalities: 1999 and 2005

Figure 4a: Attacks 1999

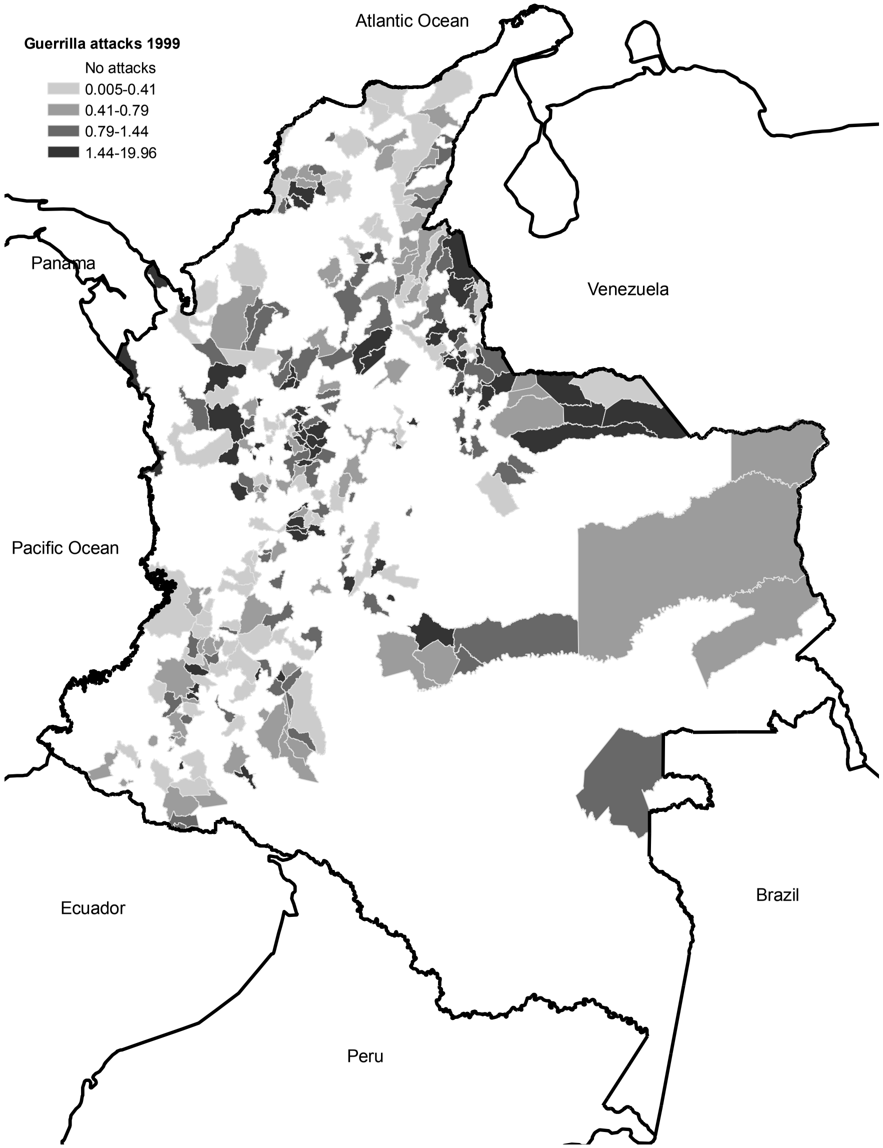
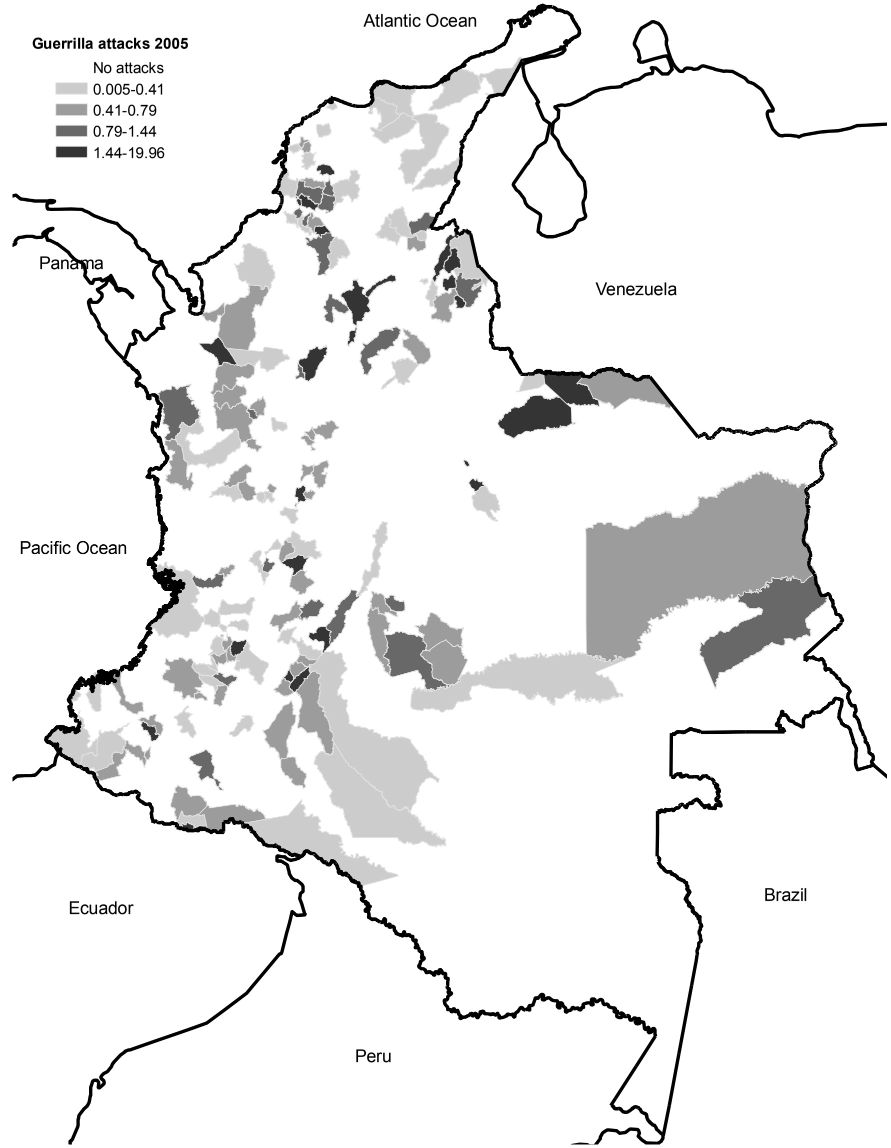


Figure 4b: Attacks 2005



Notes. This figure shows the intensity of guerrilla attacks in Colombian municipalities in 1999 and 2005, normalized by 10,000 population. *Sources*: Shape file from IGAC; conflict violence data from CERAC (see data appendix for details).

Figure 4: Spatial distribution and intensity of clashes between government forces and guerrilla groups across Colombian municipalities: 1999 and 2005

Figure 3a: Clashes 1999

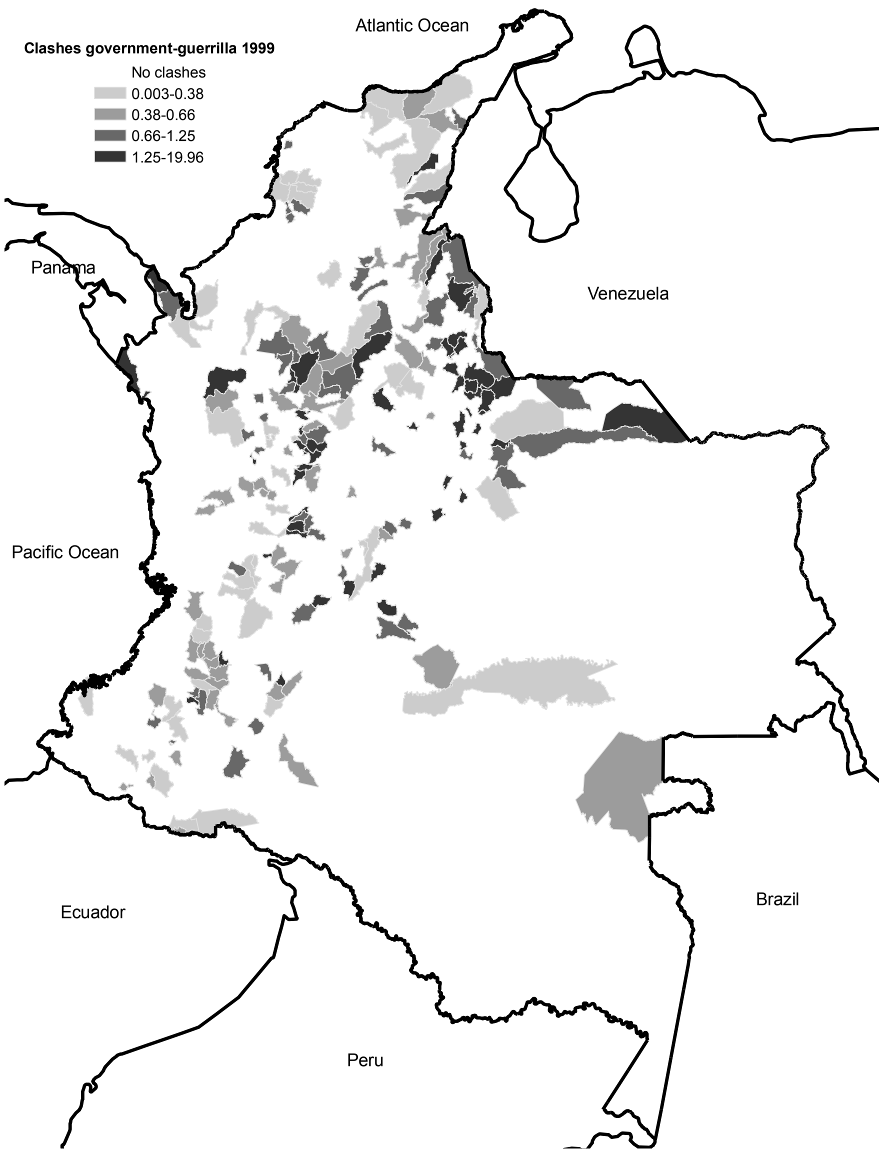
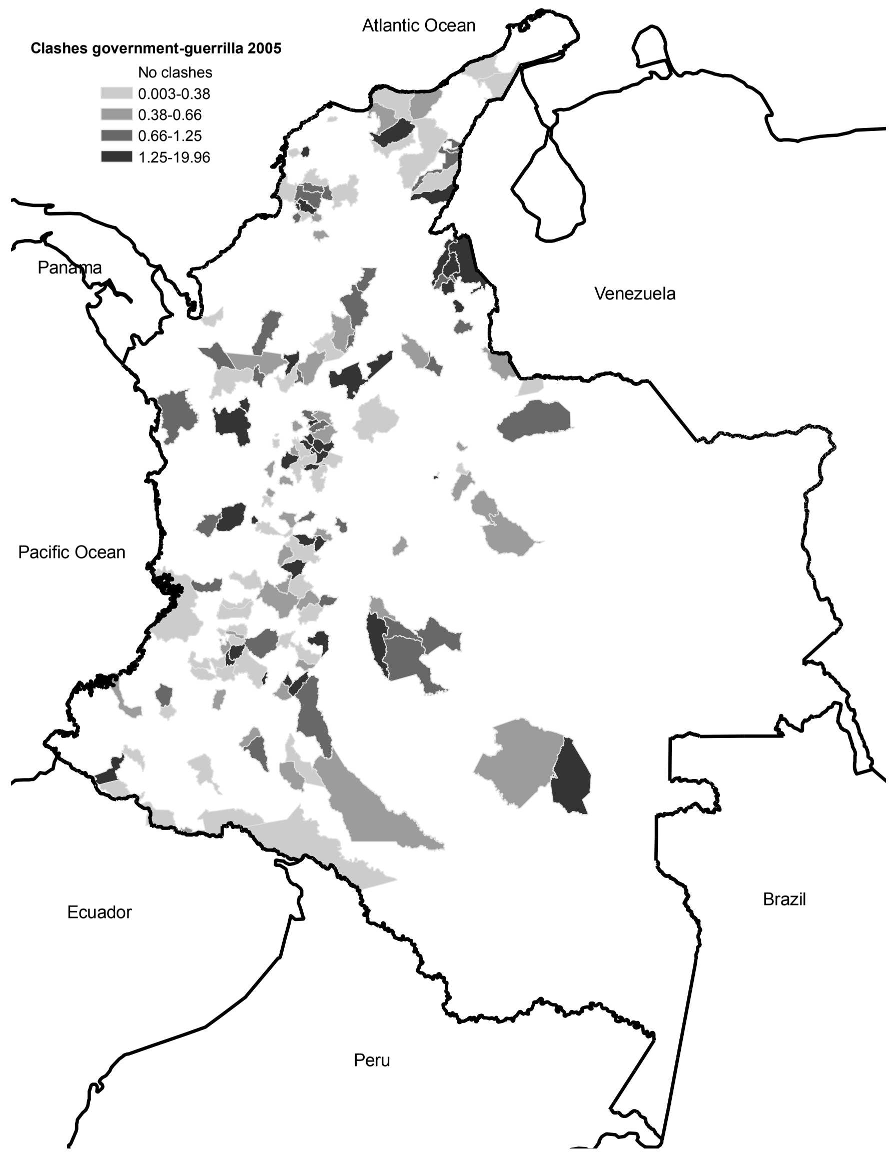


Figure 3b: Clashes 2005



Notes. This figure shows the intensity of clashes between government forces and guerrilla groups in Colombian municipalities in 1999 and 2005, normalized by 10,000 population. *Sources*: Shape file from IGAC; conflict violence data from CERAC (see data appendix for details).

Figure 5: Spatial distribution and intensity of combatant casualties in guerrilla events across Colombian municipalities: 1999 and 2005

Figure 6a: Combatant casualties 1999

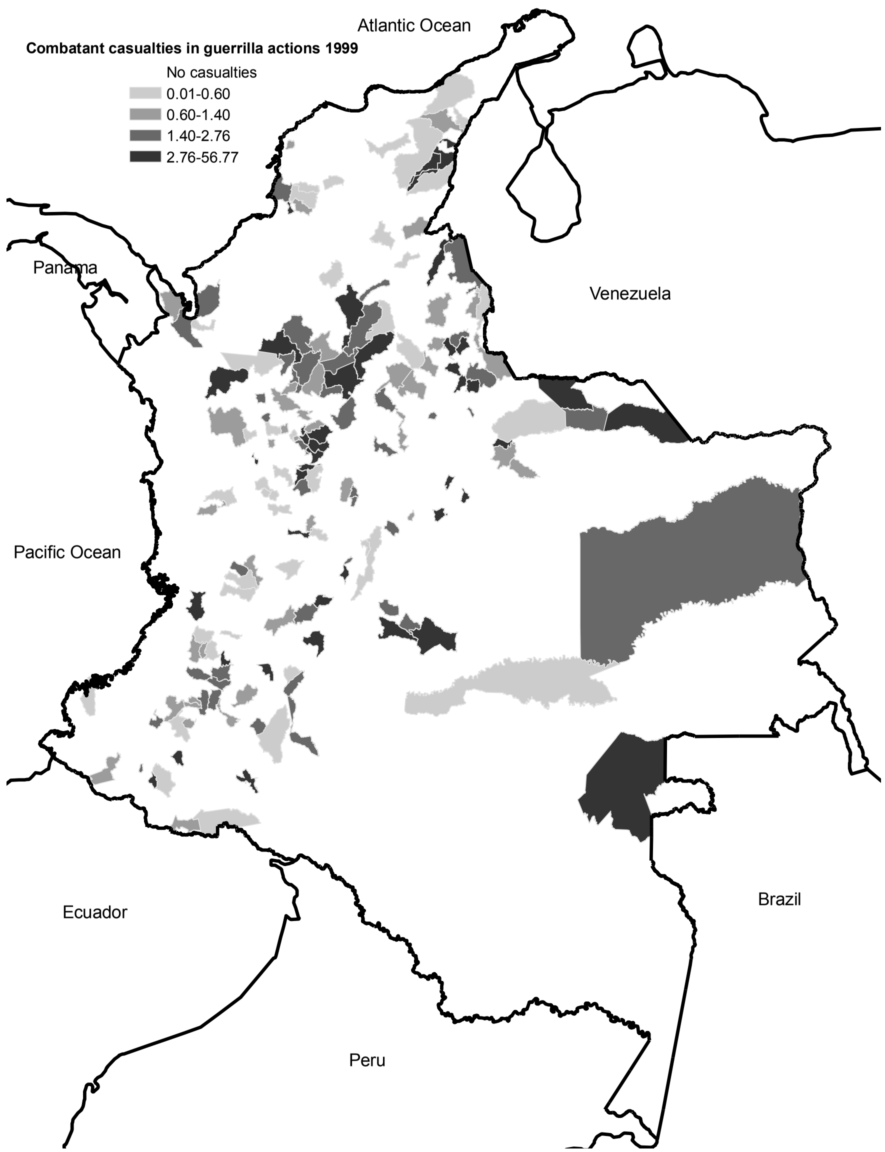
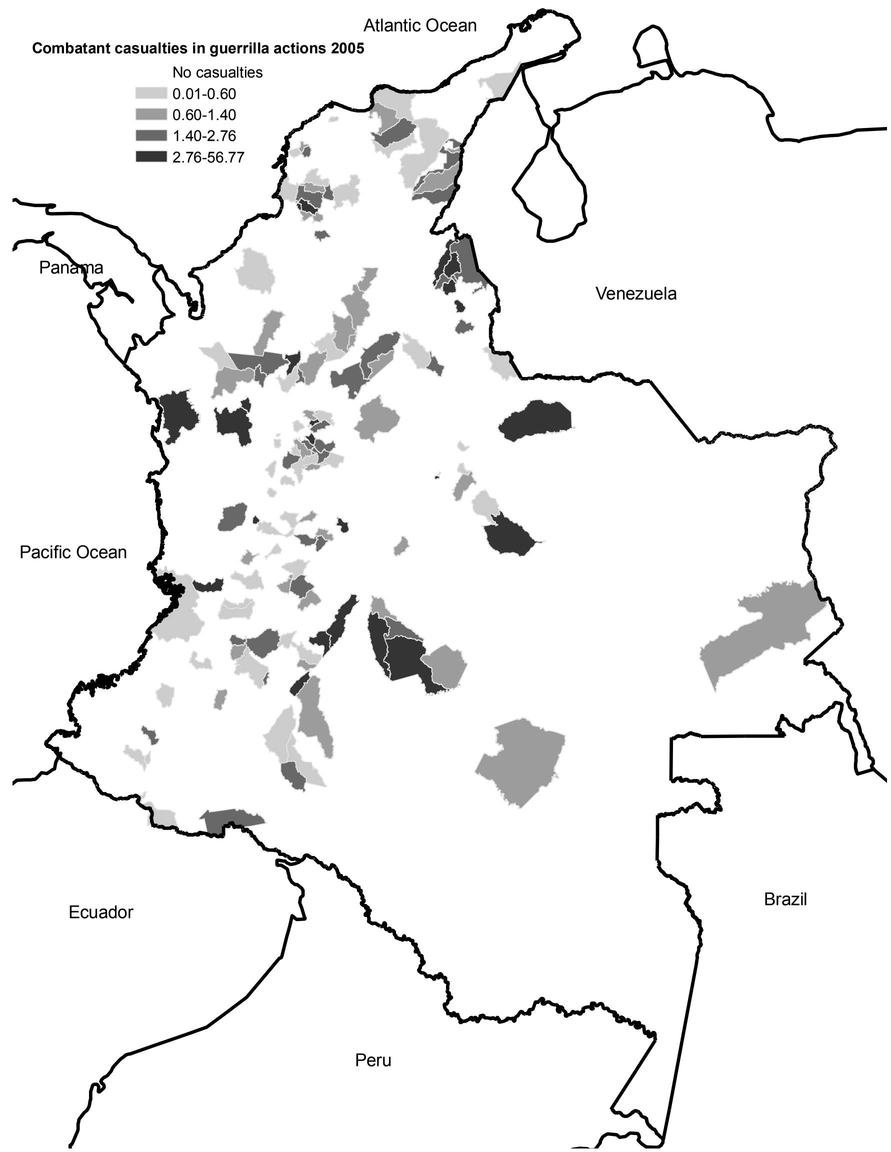


Figure 6b: Combatant casualties 2005



Notes. This figure shows the intensity of combatant casualties in guerrilla events (attacks and clashes) in Colombian municipalities in 1999 and 2005, normalized by 10,000 population. *Sources*: Shape file from IGAC; conflict violence data from CERAC (see data appendix for details).

Figure 6: Spatial distribution and intensity of civilian casualties in guerrilla events across Colombian municipalities: 1999 and 2005

Figure 5a: Civilian casualties 1999

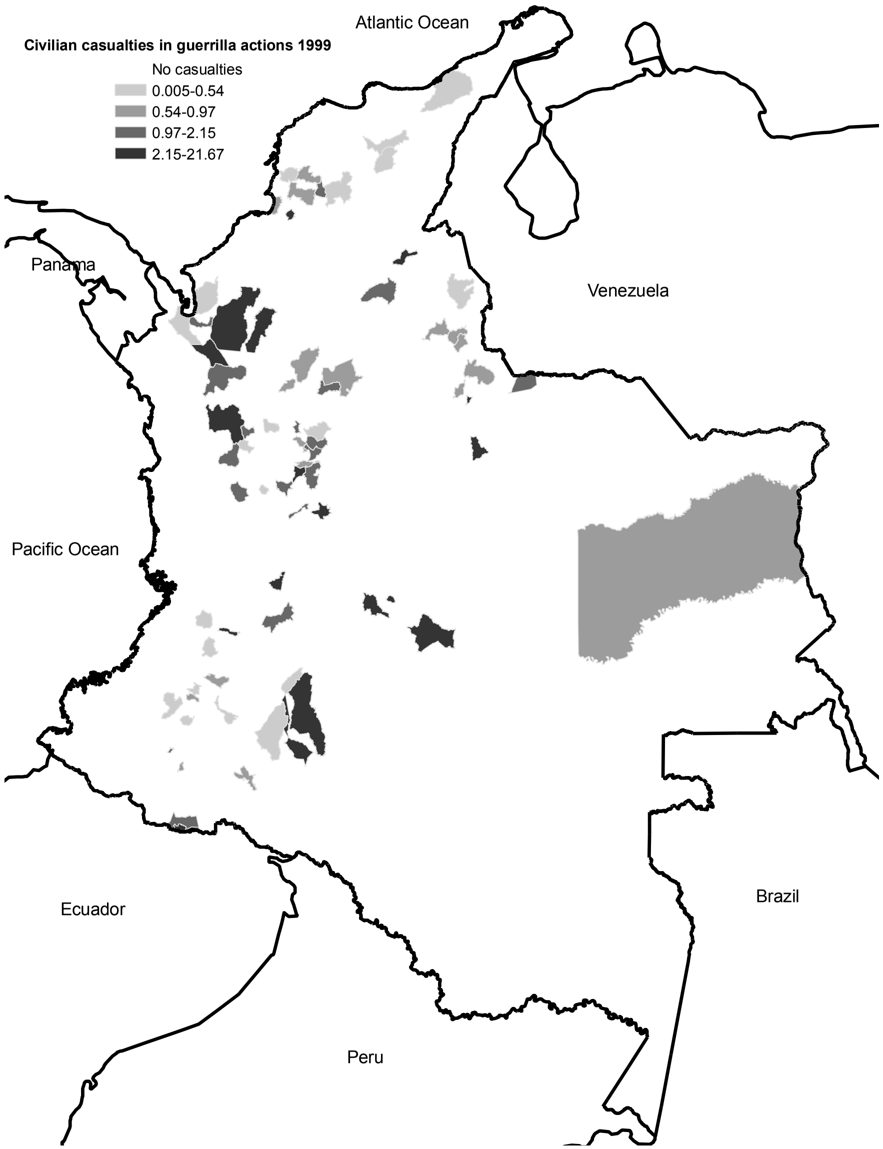
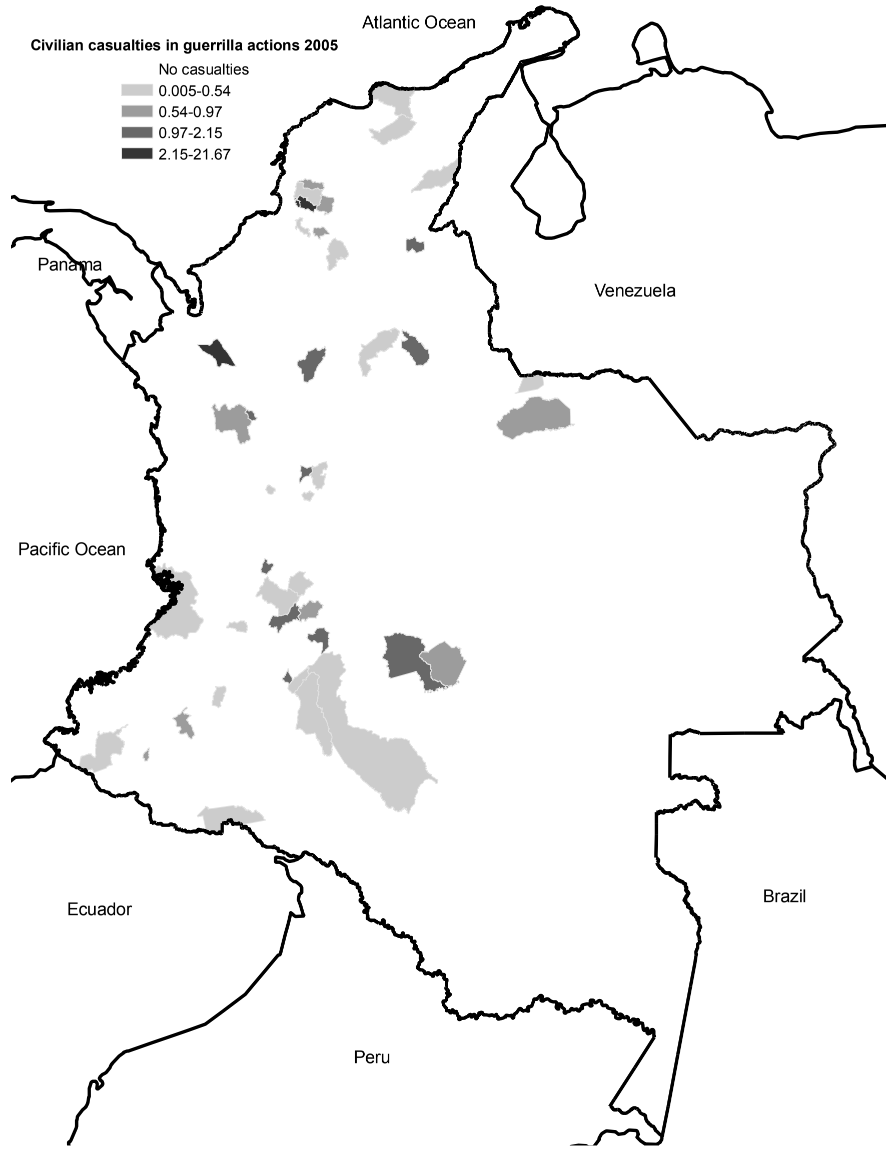


Figure 5b: Civilian casualties 2005



Notes. This figure shows the intensity of civilian casualties in guerrilla events (attacks and clashes) in Colombian municipalities in 1999 and 2005, normalized by 10,000 population. *Sources*: Shape file from IGAC; conflict violence data from CERAC (see data appendix for details).

Appendix

Our data comes from the following sources:

1. Dirección Nacional de Estupefacientes -DNE-: Dirección Nacional de Estupefacientes provided us with daily data on manual eradications as well as aerial spraying events at the municipality level, from 1999 to 2005. The illicit crop eradication policy in Colombia includes two differentiated strategies, according to the plant type and the nature of the economic exploitation of the fields: industrial exploitation of coca and opium poppy are sprayed while the small plots of the same crops and marijuana are manually eradicated. The data is event-based, and covers over 10,000 eradication related events over the period. For each event, the dataset records the date, location, type of crop eradicated, agency in charged, eradicated or fumigated area and whether the event was a manual eradication or an aerial spraying.

2. National Bureau of Statistics –DANE from the Spanish acronym-: Official population projections by municipality for the period 1995-2005 are publicly available for 1,105 municipalities. Projections are discriminated between urban and rural.

3. Centro de Recursos para el Análisis de Conflictos –CERAC-: CERAC provided us with 21,000 conflict data over the period 1988-2005 at the municipality level. For each event, the dataset records the date, location, type, perpetrator, number of victims and whether the victims were civilians or combatants involved in the incident. Each recorded incident may be classified into an uncontested attack, or a clash, which involves an exchange of fire between two or more groups. The perpetrators are either guerilla or paramilitary groups. There are two primary sources for data gathering: the first is press articles from more than 20 daily newspapers of both national and regional coverage; the second is reports from human rights NGO's and other organizations on the ground such as local public ombudsmen and, particularly, the clergy .

4. United Nations Office of Drug Control – Programa de Monitoreo de Cultivos Ilícitos (SIMCI): UNODC has supported the monitoring of illicit crops since 1999, and has produced eight annual surveys through a special satellite based analysis program called SIMCI (from the Spanish initials). The monitoring of coca cultivation in Colombia is based on the interpretation of various types of satellite images. The images cover the whole national territory (excluding the islands of San Andres and Providence) equivalent to 1,142,000 square km. Based on these surveys, we obtained an estimate of the number of hectares of coca cultivation at the municipality level. The estimation

of the total area under coca cultivation is the result of the following steps: i) identification and acquisition of satellite images; ii) image preprocessing (geo-referencing, radiometric and spatial enhancements, band combinations); iii) Digital land cover classification of land use and vegetation; iv) Visual interpretation of the coca fields; iv) verification flights; v) corrections (manual eradication, spraying, clouds and differences in acquisition dates of images that allows to get the estimates at the cut-off date of 31st December) .

5. Instituto Geografico Agustin Codazzi –IGAC-: IGAC provided us with Colombian GIS datasets, which allowed us to create maps of the variables described before. IGAC is Colombia's national mapping agency responsible for producing the official map and base cartography of Colombia, supporting geographic studies in the form of land development support and professional training and education in geographic information system (GIS) technology and coordinating the Colombia Spatial Data Infrastructure. For the past 70 years, IGAC has produced georeferenced cartographic maps at several scales using the most modern technology available at the time. IGAC also provided us with the area, and geographic coordinates (longitude and latitude) of each municipality.

6. Tropical Rainfall Measuring Mission, TRMM, NASA: The Tropical Rainfall Measuring Mission (TRMM) is a joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA) designed to monitor and study tropical rainfall. A series of quasi-global, near-real-time, TRMM-based precipitation estimates is available to the research community via anonymous ftp . The estimates are provided on a global 0.25 ° x0.25 ° grid over the latitude band 50 ° N-S.

7. Presidential Agency for Social Action, Colombia: Accion Social provided us with alternative development data at the municipality level, from 1998 to 2005. The database includes name of executing agency, municipalities covered in the project, number of hectares to be planted with legal crops and start and end date of the project. The database includes projects financed by government programs and also by USAID or both. When more than one municipality was the main location of the project, we imputed values according to the area of the municipalities involved. For example, the hectares to be planted by an alternative development project benefiting two municipalities was split into the two municipalities, and the percentage used to assign the value for each municipality was the fraction of each municipality in the total combined municipality areas. Besides, the value corresponding to the first year is the inverse of the number of years the project last; the value corresponding to the second year is the

cumulative value of the first year plus the net value of the hectares planted the second year and so on, until 2005.