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# Caught in the middle, Colombia's war on drugs and its effects on forest and people

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ABSTRACT

Coca plantations are the largest illegal agribusiness in the world, and Colombia is the world's leading coca producer. Since 1994, the Colombian state, with the aid of the US, has waged a war on drugs based on air fumigation of coca plantations. This article evaluates the social and environmental impacts of this policy. We construct and analyse statistically for the first time a spatial database with social, economic, environmental, coca production and fumigation data for all 1125 municipalities of Colombia for the period 2001–2008. We complement statistical analysis with in situ observations and secondary literature review. We find that even if the questionable government claims that overall extent of coca plantations has been reduced were to be true, still coca activity has been diffused in the territory, with devastating environmental and social consequences. Biodiversity hotspot areas are being deforested, and local populations, especially Afro-Colombian communities, are being displaced from their territories. Our statistical analysis provides quantitative evidence to back up previous claims based on victims' experience, single case-studies and ethnographic observation. We question the effectiveness of the fumigation policy and suggest that what is actually eradicated by the war on drugs is not coca, but humans and the forest.



## 1. Introduction

Coca production is the largest illegal agribusiness in the world. The global cocaine retail value is estimated at US$80–$100 billions, equivalent to 0.15% of global GDP, and at the level of the annual GDP of countries such as Iraq or Slovakia (UNODC, 2010). Cocaine, consumed mostly in North America and Europe, is primarily produced in the Andean region. The plantation of coca crops for cocaine is concentrated in three countries: Colombia, Peru and Bolivia. Since 1997, Colombia is the main coca producer, accounting for more than 50% of total world production, with some 81,000 ha of coca cultivated and 450 metric tons of cocaine produced in 2008. Coca production in Colombia accounted for 623 millions of dollars of revenue in 2008, 0.3% of GDP and 3% of agriculture's GDP (UNODC, 2008a). Unlike Peru and Bolivia, whose anti-drug policy is based on manual eradication, Colombia is the only country in the world to use aerial fumigation.

Colombia's fumigation policy began cautiously in the end of the 1970s in order to fight marijuana plantations, but was extended in 1994 to the expanding cultivations of coca. Aerial fumigation intensified and proliferated with the signing of 'Plan Colombia' in 1999 by Colombia and USA and the subsequent creation of the "Program of Eradication of Illicit Crops with Glyphosate" in 2000. Plan Colombia has been celebrated as a great success in reducing the total area of the country occupied by coca from 144,800 ha in 2001 to 81,000 ha in 2008 (UNODC, 2010), presumably liberating local populations from the grip of the illegal business and its devastating consequences. The Colombian government has also heralded the environmental benefits of the war on drugs; the coarse hypothesis behind such statements is that coca has negative environmental effects and any policy that reduces must by definition have positive ones (Álvarez, 2007; Bernal, 2007). Yet, other researchers argue that fumigation goes hand-in-hand with deforestation and environmental degradation (Ávila et al., 2007; Vargas, 2004; Walsh et al., 2008a), negative health effects (Ávila et al., 2007; IDEA, 2005; Nivia, 2001a), and social impacts, including forced displacement, disproportionately falling on Afro-Colombian groups and low-income population (Defensoria del Pueblo, 2007; OAIPC, 2010).

How does aerial fumigation affect coca production, the livelihood and settlement patterns of human populations and the state of ecosystems? This is an important question if one wants to know how and why anti-drug interventions "from a safe distance", such as aerial fumigation, may produce counterproductive results at the ground that undermine their proclaimed intentions. We provide new evidence at a finer spatial scale than ever before, which substantiates the claim that aerial fumigation has negative social and environmental effects, and we then explain why this is the case. We argue that the aerial fumigation policy is ill-suited for the socio-environmental interdependencies present at the complex

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socio-ecosystem of the Colombian forests, where most of coca production is concentrated. In this, we position our research as a case study of the broader thesis about the failure of State improvement schemes based on schematic visions that do violence to complex socio-ecosystem interdependencies (Norgaard, 1994; Scott, 1998).

We are not the first ones to study the social and ecological impacts of cocaine production or the war on drugs. There is a long literature on the failures of the US-driven war on drugs in Latin America and particularly the negative effects of the forced displacement of cultivations (Guáqueta, 2005), compared to more structural solutions offering employment alternatives to producers (Guridi, 2002). The failure of forced policies to make peasants to leave cocaine production has been documented for the case of Bolivia (Guridi, 2002) and Peru (Cabieses, 1999). A grand part of the literature on aerial fumigation evaluates direct impacts, most notably on health (e.g. Ávila et al., 2007; Hewitt et al., 2009; IDEA, 2005; Nivia, 2001a; Solomon et al., 2005a, 2005b), and the environment and agriculture (Ávila et al., 2007; Eslava et al., 2007; Messina and Delamater, 2006; Nivia, 2001a, 2001b; Varona et al., 2009). Concerning indirect effects, there are studies, which have looked at the displacement of peasants and legal crops in Bolivia and Peru (Bradley and Millington, 2008). For Colombia there is anecdotal evidence that the fumigations destroy the revenue base of the peasant economy and displace both coca production and peasants to new areas (Vargas, 2004). Scrutinizing the official data at the national level, González (2006) finds inconsistencies that raise questions about the proclaimed effectiveness of the eradication policy. Also an inter-temporal econometric analysis at the national level by Moreno-Sanchez et al. (2003) shows that the cultivation area of coca in Colombia has increased as eradication efforts have intensified, because farmers compensate for eradication by cultivating the crop more extensively. This pattern is confirmed by a statistical analysis at the level of the 32 sub-national departments of Colombia by Dion and Russler (2008), who find that fumigation displaces, but does not eradicate, coca production. This displacement effect has been called in the drugs literature the "balloon effect" (Laffiteau, 2010; UNODC, 2008b) and attributed to an inelastic demand, that will be satisfied in one way or the other by the producing regions.

Whereas this literature offers many useful reference and entry points, there are several gaps if one wants to get a more accurate picture of how aerial fumigations affect production, settlement and ecological patterns in Colombia. First, the national or regional scale analyses hide important shifts and effects at lower spatial scales, where complex interdependencies are at play. We provide here for the first time data coverage on fumigations and coca cultivation down to the municipal level (1125 municipalities). Second, much of the interest until now has been on production patterns, and the effects of fumigation on the acreage and location of coca cultivations. Despite claims for the dislocation of people or the uneven impacts of the policy on the basis of race or class, no other study to our knowledge has examined such effects rigorously. We cover a greater number of variables per year (also for a more recent period, 2001–2008, than other studies) identifying new associations between coca cultivation and its social impacts, especially dislocation, which has not been evaluated before. Third, concerning environmental impacts, whereas Dávalos et al. (2011) before us also looked at the complex relations between illicit crops and deforestation in Colombia at the municipal level, we extend his analysis by using a different methodology on the basis of a mapping of ecosystems which permitted us to evaluate land-use changes at the ecosystem level (see methods below). Fourth, and most importantly, this is the first study that attempts an integrated and multi-dimensional analysis of both direct and indirect effects of fumigations at the most refined scale possible. Whereas other studies before focused either on health, environmental or production effects, we examine all these together. This gives us the opportunity to offer a more accurate understanding of the multi-faceted effects of fumigation on people and the territory, and through it draw wider claims on how improvement schemes and anti-drug policies from a distance produce negative effects in complex socio-ecosystems such as those of Colombia.

In summary, our main claim is that the fumigation policy is failing in Colombia, because it does not eradicate, but diffuses coca production, shifting it to forests of ecological importance and to areas inhabited by low-income, especially Afro-Colombian and indigenous communities, which as a result are increasingly displaced. The broader significance of our claim is the confirmation of a broader pattern whereby government "improvement" policies imagined from a distance fail miserably in the face of complex local socio-ecological interdependencies.

Section 2 presents the methods used to generate the evidence for this claim and the new data mobilized or constructed for this analysis. We employ a novel spatial approach to respond to the above questions demonstrating the importance and contribution of geographical analysis. In particular, we analyze statistically a newly-compiled geographical and longitudinal dataset of aerial fumigation, coca production and various socio-economic and demographic variables at the municipal level, complementing it with qualitative information from interviews and secondary documents, as well as in situ assessments of the impacts of aerial fumigation.

Section 3 presents the empirical evidence that supports our claim. We find that:

1. Fumigation has not eradicated, but displaced coca production to other regions. Such a "Balloon effect" has been noted by others for manual eradication and at the macro-regional level (Bradley and Millington, 2008; Laffiteau, 2010; The Economist, 2001; UNODC, 2008a). Our intra-national study finds in addition that aerial fumigation not only displaces, but actually diffuses the production of coca in the territory, and that the effect of fumigation is temporary, as production often returns after a while. This creates a negative spiral of fumigation and cultivation that affects more and more territories and people.
2. Fumigation in Colombia displaces production to areas of primary forest of great environmental significance.
3. Fumigation causes negative health impacts but these are contested and hard to verify. The level of complaints launched by local communities suggests that fumigations do impact negatively local livelihoods.
4. Fumigation is associated with increased human displacement.
5. Less developed communities, including indigenous and Afro-Colombian communities, are disproportionately impacted by fumigation and coca displacement. There is no evidence however to suggest discriminatory fumigation by the authorities.

Section 4 discusses the main findings of our research and attempts to explain why is the policy failing. We argue that the policy overlooks complex interdependencies at the local level, and in particular does not account for the lack of alternative sources of income, as well as the particular socio-ecological features of the coca economy, which make it selectively shift to areas of primary forest and low development. Section 5 reinstates our main conclusion and draws its policy implications: the Colombian anti-drugs policy of aerial fumigation has caused a displacement and diffusion of coca cultivation in the territory, impacting socially and ecologically vulnerable areas and expanding the war on drugs to new areas, affecting the livelihoods of more people. We add our voice to those who argue that the US and Colombian governments should reconsider thus policy and shift resources instead to policies that curb demand for drugs at its source or that

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provide meaningful livelihood alternatives to local populations at the production regions.

## 2. Data sources and methods

The research findings discussed in this article were gathered following a multi-evidentiary strategy consisting of four components. First, an extensive literature review was conducted of all peer-reviewed and government publications concerning antidrug policies and the social, economic, environmental and political aspects of coca plantations in Colombia. This preliminary phase of the research benefited by discussions with experts of the Integrated Illicit Crops Monitoring System (SIMCI in Spanish), the National Office of Narcotics of Colombia (DNE in Spanish), the Ministry of Defense, and the NGOs Transnational Institute (TNI), the Arcoiris Foundation and Acción Andina, as well as other researchers from Colombian Universities.

Second, and at the heart of the research findings is a database at the municipal level, the first of its kind, including data for all 1125 municipalities of Colombia with respect to social, economic, environmental and institutional features, as well as information on the extent of coca production and aerial fumigation. We used existing data but we are the first ones to construct this comprehensive database for the purposes of this research. The data for municipal coca production (2001–2008) are taken from the official data produced by SIMCI, whereas for fumigation we used municipal level data from the DNE, which has been reported by UNODC (UNODC, 2008b, 2009). Such official data is highly suspicious and controversial, as it is often invoked to support the success of the government's anti-drug policy. Data from CIA's Crime and Narcotics Center (CNC) suggests a lesser impact for the fumigation program (GAO, 2008). However the CNC data is available only at the national and not the municipal level. Unfortunately, the SIMCI/UNODC data is the only source available at the municipal level and with this we had to work. Since we are interested more on longitudinal cross-sectional differences the possible biases in the absolute levels are less crucial for our case. Furthermore, we will show that even with this government data that may have been manipulated to paint a better picture, a disaggregated analysis at the municipal level shows that the fumigation policy is failing.

Table 1 details the variables used in the database, their definition and the sources of the data. This list was constructed on the basis of the literature review and our initial research questions after consultation with experts and taking into account the availability of data at the municipal level. On the basis of this database, we tested (spatial association and correlation analysis) hypotheses concerning the socio-economic characteristics of the expanding coca frontier, and the relationships between aerial fumigation, the spatial distribution of coca production, environmental effects and population displacement. The statistical significance of the correlations was carried out using 10,000 permutations (Anselin, 2005; Anselin et al., 2002). Analysis of spatial information and the statistical tools were done using the software SPSS, Geoda and ArcGIS.

Third, we analyzed the deforestation and ecosystem impacts of coca cultivations by overlapping information about land coverage from the national map of ecosystems in 2000 in shape format (IDEAM et al., 2007) with geospatial information about coca cultivations from SIMCI's maps for the 2001–2008 period. A total of 154 ecosystems were grouped into three principal and 32 sub-biomes. Sixteen types of land cover were grouped into eight natural classes (natural continental waters, shrubs, natural forests, grasslands, grasses and coastal bushes, continental hydrophytes, coastal lakes and estuaries, and secondary vegetation) and eight transformed classes (heterogeneous agricultural areas, largely alternated areas – agro industrial crops, urban areas, artificial continental water, forest plantation, annual or transitory cultivations, (semi-) permanent crops and grasses). Our analysis was based in the natural cover and ecosystems estimated in 2000 (IDEAM et al., 2007) and the expansion of coca crops during 2001–2008 (Coca census 2001–2008). We estimated the share of natural ecosystem transformed at the municipality level. Where relevant, we also used maps (shape format) divided according to the legal status of Colombian territories into: Collective territories of Afro-Colombian communities, indigenous territories, forest reserve, natural national parks and subtracted area from the forest reserve (subtracted area means the area that ceases to be in forest reserve) (Accion Social, 2009), allowing in this way to document differentiated changes in cultivation and fumigation in each of these territories. The results were complemented with data from the United Nations Office on Drugs and Crime. Dávalos et al. (2011) before we also looked at the complex relations between illicit crops and deforestation in Colombia. He used however remote sensing images, and where heavy clouds did not allow a clear picture, the data was classified as missing. This was a problem especially for the Pacific region and likely to lead to an underestimation of deforestation. Our analysis which overlaps municipal and ecosystem data does not suffer from this problem, though we might have overestimated deforestation due to coca in cases where what was classified as natural forest in 2000 was already transformed to agriculture and another type of land use and only after that turned into coca cultivation.

Fourth, a rapid assessment was conducted in the department of Nariño (Map 1), one of the areas most affected by the expansion of illicit coca crops in the 2000s. Between 2001 and 2008 the department of Nariño had an increase of 162% of the area cultivated with coca crops and it has been a growing target of fumigations. During a period of 1 month of field-work, the first author interviewed a total of 18 people, 10 of them representing those to different degrees of affected by or involved in coca production (including indigenous leaders, Interior departmental advisers, members of the health department secretary, members of the national police) and eight people from local communities. Additional information on the impacts of fumigation on the local population was collected through a review of governmental documents from the Ombudsman, the local police, the health secretary and the hospitals of Nariño and through direct conversations with local people, particularly with five peasants from the coca-growing areas of the department of Nariño and leaders of the indigenous community indigenous Awá that inhabit the southwest of Colombia, one of the communities most affected by armed conflict in Colombia and the war on drugs (Saavedra, 2009).

Below we report on the key findings of our analysis structured around each of the five sub-claims identified in the introduction. The core findings are based on the municipal statistical research and the ecosystem impact assessment, grounded where relevant with material from secondary literature research and the Nariño visit.

## 3. Evidence

### 3.1. The effects of aerial fumigation on coca production

According to the government data that we used, between 2000 (commencement of Plan Colombia) and 2008, coca cultivations at a national level have been reduced from an area of 163,000 ha to half, i.e. 81,000 ha. However, unlike what the government claims, CIA's Crime and Narcotics Center (CNC) has reported that between 2001 and 2007 the area cultivated with coca has remained stable at around 170,000 ha (GAO, 2008). Rather than such national aggregates, we are more interested in the territorial distribution and im-

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**Table 1**
Description of variables included in the analysis.

| Name | Variable name | Years | Source | Unit | Description |
|---|---|---|---|---|---|
| PRD | Primary road density | 2005 | Road map (shape) by Geographic Institute Agustín Codazzi – estimation by the authors | M/ha | Meters of primary roads per hectare |
| FDP | Forced Displacement of Population | 2001–2008 | Presidency of the Republic of Colombia – Presidential Agency for Social Action and International Cooperation | Number of displaced people | Number of forced displaced people by violence and conflict. This information is taken from the National System of attention to Displaced People (''Sistema Nacional de Atención Integral a la Población Desplazada'') |
| RUBN | Rural Unsatisfied Basic Needs Index | 2005 | National Administrative Department of Statistics – (DANE Spanish acronym for ''Departamento Administrativo Nacional de Estadística'') | Index from 0 to 100 (from 'no basic need satisfied' to completely satisfied) | The index is determined through five indicators: adequacy of housing, degree of household overcrowding, adequacy of basic household services, degree of economic independence of the household; household with children at school-age which are not attending school |
| IMD | Index of municipal development | 2001–2008 | National Planning Department of Colombia (DNP – Spanish acronym for ''Departamento Nacional de Planeación'') and Direction of territorial sustainable development (DDTS – Spanish acronymun for ''Dirección de Desarrollo Territorial Sostenible'') | Index from 0 to 100 (where 0 means low municipal development) | Synthetically measuring the performance of municipalities in social and financial indices, including: % of households with water supply, % of households with sewage, % households with energy services, % of people without unsatisfied basic needs in urban area |
| VAIA | Number of violent acts by illegal armed groups | 2001–2006 | Los Andes University Bogotá and Ministery of defense Colombia | Number of violent acts | Number of violent acts by Illegal Armed Groups (FARC, AUC, ELN) per Municipality, Including terroristic acts, assaults, attacks, roadblocks, ambushes, harassment, attacks on population |
| MR | Murder Rate by Illegal armed groups | 2001–2008 | Colombian National Police – Estimation by the Authors | Number of homicides | Number of homicides per 100,000 inhabitants committed by illegal armed groups (FARC, AUC, ELN). Homicides committed by common crime are not taken into account |
| MIAG | Number of murders by Illegal armed groups | 2001–2008 | Colombian National Police | Number of homicides by Illegal armed groups | Homicides committed by common crime are not taken into account |
| PPF | Percentage of primary forest area | 2000 | Colombia Ecosystem map (shape) – Institute of Hydrology, Meteorology and Environmental Studies of Colombia (IDEAM – Spanish acronymun for ''Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia) – Estimation by the authors | Percentage | Hectares of primary forest as percentage of the total area of the municipality |
| PCOCA | Percentage of coca area | 2001–2008 | Coca maps (shape) – Integrated Illicit Crops Monitoring System (SIMCI: Spanish acronym for ''Sistema Integrado de cultivos ilicitos'') | Percentage | Hectares of cultivated coca as percentage of the total area of the municipality |
| NCOMP | Number of complaints to the Ombudsman by citizens concerning aerial spraying | 2001–2008 | Local and National Ombudsman's Office | Number of complaints | Number of complaints to the Ombudsman by citizens concerning aerial fumigation |
| AF | Aerial fumigation | 2001–2008 | National Direction of Narcotics (DNE – Spanish acronym for ''Dirección Nacional de Estupefacientes'' | Number of hectares | Number of fumigated hectares per municipality |
| CA | Coca area | 2001–2008 | Coca maps (shape) – Integrated Illicit Crops Monitoring System (SIMCI: Spanish acronym for ''Sistema Integrado de cultivos ilicitos'') | Number of hectares | Ha of area cultivated with coca in the municipality |
| RPOP | Rural population | 2005 | National Administrative Department of Statistics – DANE, estimation by the authors | Number of persons | Number of persons living in the rural zones of each municipality |
| AF01-08 | Area fumigated between 2001 and 2008 | Total 2001–2008 | National Direction of Narcotics (DNE – Spanish acronym for ''Dirección Nacional de Estupefacientes'' | Number of hectares | Total area fumigated between 2001 and 2008 |
| SDC01-08 | Indicator of variation in coca cultivation | Total 2001–2008 | Coca maps (shape) – Integrated Illicit Crops Monitoring System (SIMCI: Spanish acronym for ''Sistema Integrado de cultivos ilicitos'') | Number of hectares | Standard deviation of the area of coca cultivated from the 2001–200 |
| ABC and AIT | Area of the municipality belonging to Indigenous territories and black communities | | Maps of black communities and Indigenous territories (shape) – Geographic Institute Agustín Codazzi | Number of hectares | Number of hectares under legal status of indigenous territory (AIT) or under title of black communities (ABC) |
| AECO | Area of natural cover and natural ecosystems at municipal level | 2000 | Colombia Ecosystem map (shape) – Institute of Hydrology, Meteorology and Environmental Studies of Colombia (IDEAM – Spanish acronymun for ''Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia) – Estimation by the authors | Number of hectares | Hectares of natural cover of a certain ecosystem type within the municipality |

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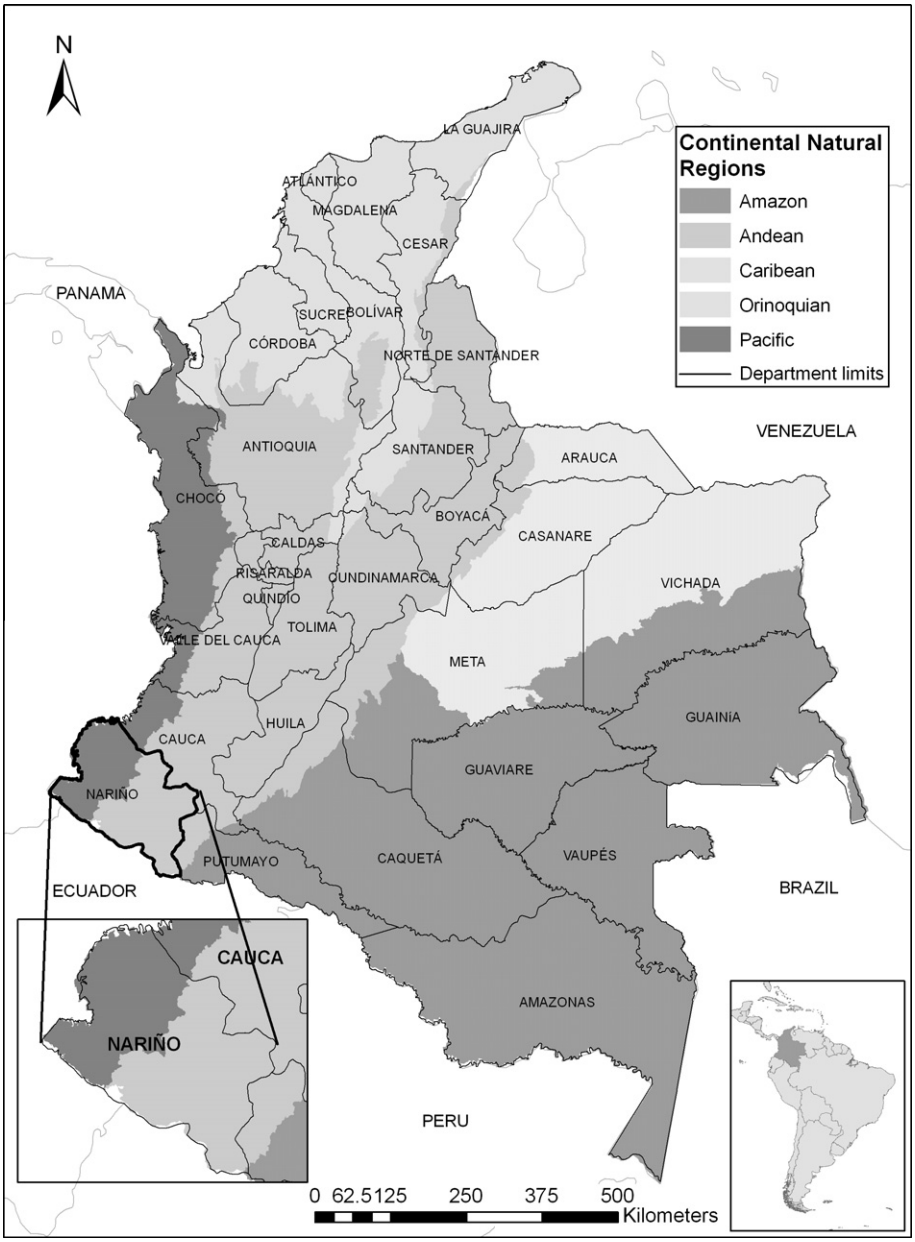
**Table 1** (*continued*)

| Name | Variable name | Years | Source | Unit | Description |
|---|---|---|---|---|---|
| CALS | Area cultivated with coca in each of the main territorial divisions according to legal status | 2000–2008 | Coca maps (shape) – Integrated Illicit Crops Monitoring System (SIMCI: Spanish acronym for "Sistema Integrado de cultivos ilicitos") and maps of black communities territories, Indigenous territories, National Natural parks, Subtracted area from forest reserve – Geographic Institute Agustín Codazzi | Number of hectares with coca in each of the legal status of the territory selected, by year | Number of hecatares with coca crops in Afro-Colombian territories, indigenous territories, forest reserve, subtracted area from the forest reserve and national natural parks |

pacts of coca production. We will show that even with the use of the official government data that should have been favorable to the effects of fumigation, it appears that fumigation policy has not eradicated, but diffused production through the territory, especially in socially and ecologically vulnerable zones, affecting the lives of more people.

Before the start of fumigations, most coca cultivations were concentrated in the northern region of Colombia, at the Colombian Amazon (Map 1). In 2000 the three departments of the Amazon region alone (Putumayo, Guaviare and Meta), out of the total of 32 departments in which Colombia is divided, accounted for 58% of the national production of coca. And it was there that 56% of the fumigations in 2000 concentrated. However, following the fumigation policy coca production was dispersed to new regions principally in the Pacific region (Nariño and Chocó departments). We demonstrate this "balloon effect" (Paredes and Correa, 2007) in




**Map 1.** Departments and natural (continental) regions of Colombia.

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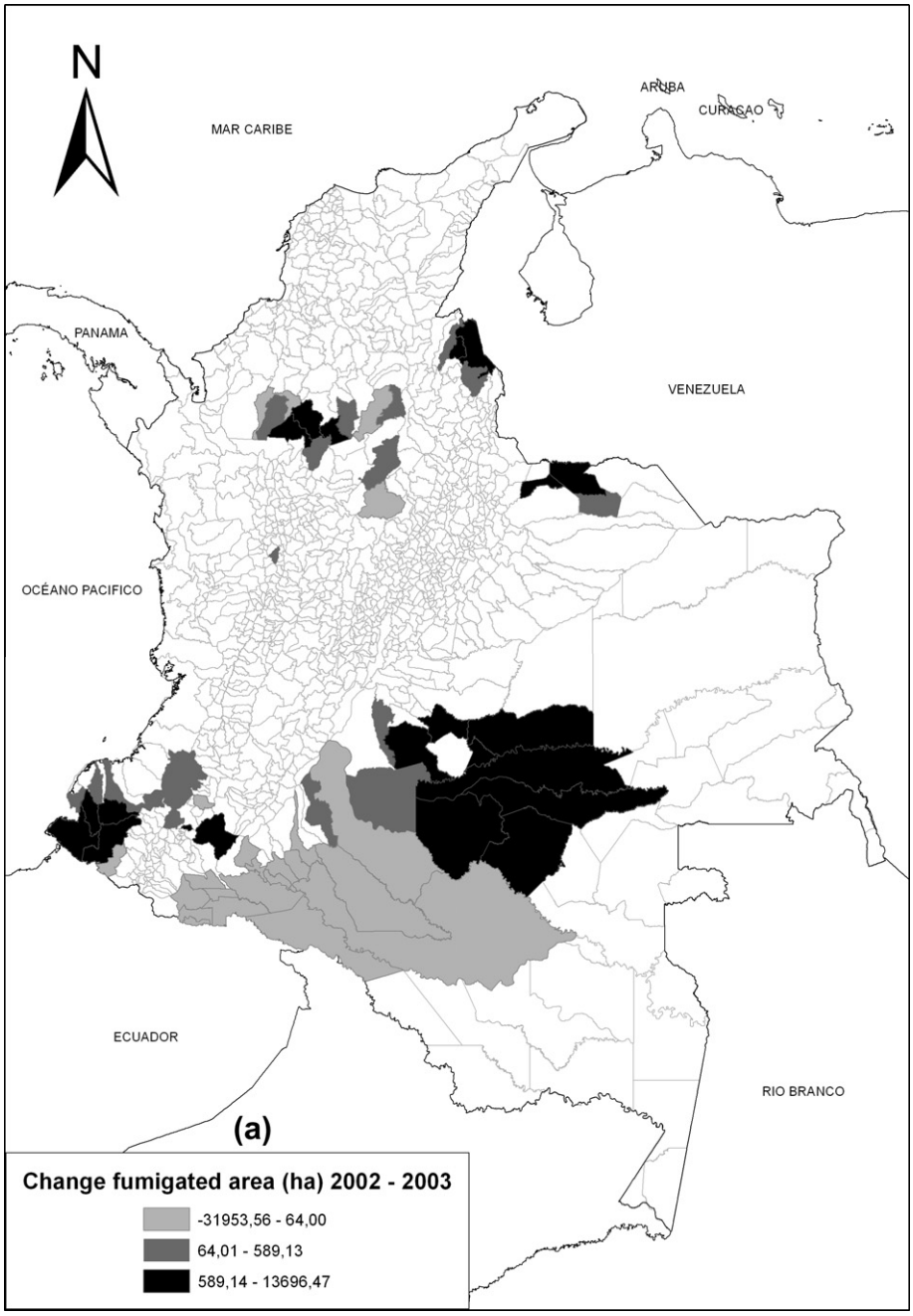


**Map 2.** (a) Change fumigated area 2002–2003 and (b) change coca area 2003–2004.

four ways: (1) graphically (Maps 2 and 3), (2) statistically (Table 2), (3) with a cross-sectional municipal analysis (Fig. 1 and Map 4) and (4) in Section 5, with a case-study (Fig. 2). Since our analysis focuses on the fumigation policy, we do not include manual eradication. This makes it likely that we are overestimating the effects of fumigation in causing the "balloon effect". Note however that fumigations have affected a greater part of the territory than manual eradication (172,000 ha vs. 41,000 ha in 2006, and 13,300 vs. 95,000 ha in 2008; (UNODC, 2006b, 2008b, 2009).

Maps 2 and 3, which are derived from our municipal database (Table 1), compare changes in area fumigated (2002–2003 and 2006–2007) with changes in the area occupied by coca crops in the subsequent year (2003–2004 and 2007–2008). We find that in the municipalities where fumigations increased (black color – Maps 2a and 3a), the extent of land covered by coca area declined in the subsequent period (gray color – Maps 2b and 3b). However there was an increase in the extent of the cultivated area in the municipalities neighboring the areas fumigated (black color – Maps 2b and 3b). Therefore the shrinking of coca production in one part came at the expense of expanding in another. In other words, even if overall coca cultivation were to be decreasing (as the official data claims), it is nonetheless diffusing in the territory.

In addition to the visual representations of Maps 2 and 3, we test the proposition of a balloon effect by analyzing statistically the spatial association between the fumigated area by municipality for the year $n$ and the area under coca in the bordering municipalities in the year $n + 1$. The estimation was done using the multivariate Moran's I coefficient, an indicator of spatial correlation (Anselin et al., 2002). We found a positive association between the area fumigated in a municipality in year $n$, and the area under

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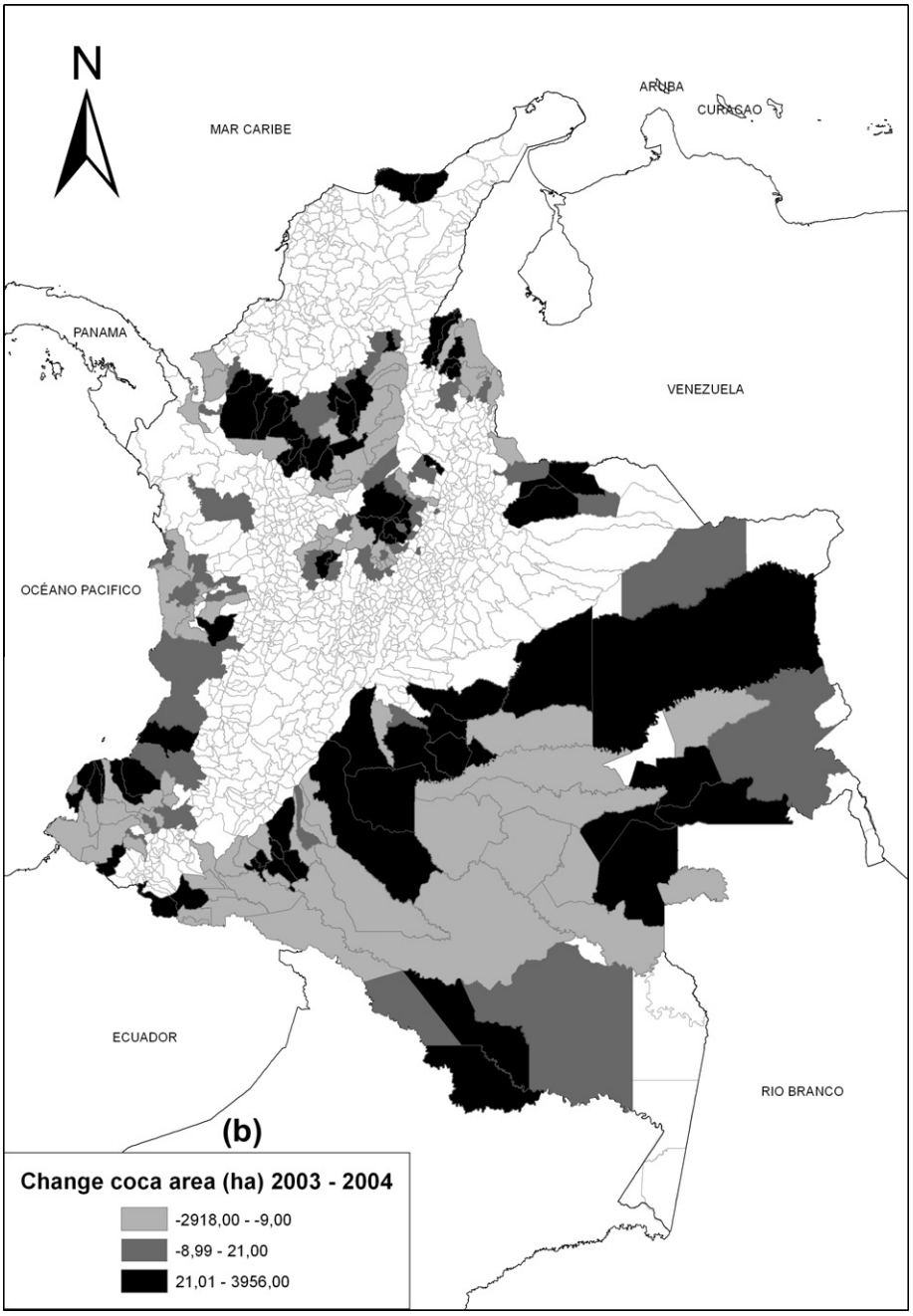


**Map 2.** (*continued*)

coca plantation in bordering municipalities in the year $n + 1$ (Table 2). In other words, there is a direct association between aerial fumigation of a municipality and subsequent increase of coca production in a nearby one. This finding of a "balloon effect" is not unique to aerial fumigation or Colombia, but has also been observed in the cases of manual eradication programs in Bolivia and Peru (Bradley and Millington, 2008; Salisbury and Fagan, 2011).

Correlation is not causation. First, while we can ascertain expansion in neighboring areas after fumigation, we do not have data to document actual displacement. However it is not farfetched to hypothesize that expansion in neighboring areas is the result of displacement, as corroborated by many of our interviews.

Second, it can be that the departure of coca production from one area is the result of other factors, such as a coca production saturation effect, increased local conflict or changes in labor conditions. The hypothesis here would be that the areas experiencing these changes would be the ones with more intense development of coca production and hence the ones more likely to be fumigated. Fumigation therefore would correlate with expansion in neighboring areas (through displacement) but with no causal relation. Again, such factors were not identified as important either in the literature review or the interviews, but of course these alone cannot rule them out. Given however that we compare fumigation at time $n$ with neighboring production at time $n + 1$, we find it less plausible that such a clear "cat and mouse" dynamic would emerge simply by fumigation following year after year saturated or conflicting areas, i.e. zones where production was already at the point of moving to a neighboring zone. What we cannot rule out however is the possibility that fumigation acted in concert with some of these or other factors to cause the migration of production; for example it

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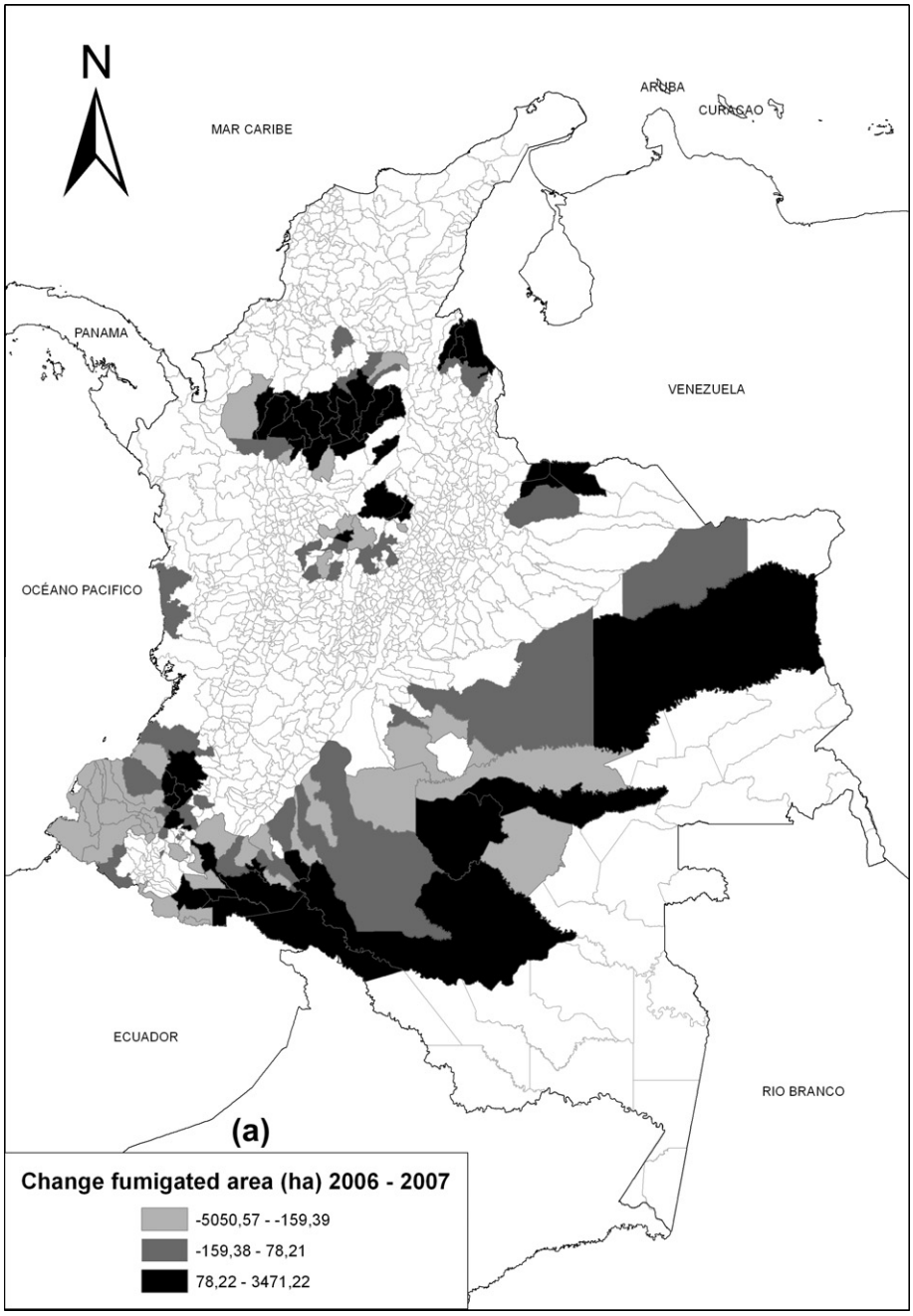


**Map 3.** (a) Change fumigated area 2006–2007 and (b) change coca area 2007–2008.

can be that the areas fumigated were also the ones where there were other forms of confrontation or violence causing displacement of cultivation, and so displacement was not the effect of fumigation alone. Further research is necessary to isolate the causal contribution of each factor and their interactions.

Contributing to the understanding of the balloon effect, we find that it is not so much the case that the geography of coca production is shifted from one area to the next, but that production is diffused across municipalities. The number of municipalities with coca plantations within their territories increased from 164 in 2001 to 202 in 2008 (Fig. 1). All the new (to coca) municipalities have plantations that exceeded 100 ha, suggesting that there is extensive cultivation going on, and that this is not a minor side-effect. Furthermore, while by 2001, only 85 municipalities had coca cultivations exceeding 100 ha, by 2008 the number of municipalities with such extensive cultivations had increased to 106.

This expansion of the cultivation to new territories, has produced a subsequent increase of aerial fumigation in the new territories. In turn, and in a vicious cycle mode, this appears to have caused new displacement of coca cultivations. Interestingly in some cases, this has caused a return to areas previously fumigated. A consequence is that the number of municipalities fumigated increased accordingly. Fig. 1 shows that in 2001, 50 municipalities were fumigated, but this number increased to 97 in 2008. Rather than an intensification of the policy, this can be seen as evidence of its failure to eradicate coca production in the targeted areas. The result is the geographical expansion of both coca and the war on drugs frontier. Map 4 illustrates spatially the persistence of coca production in the territory by indicating the number of

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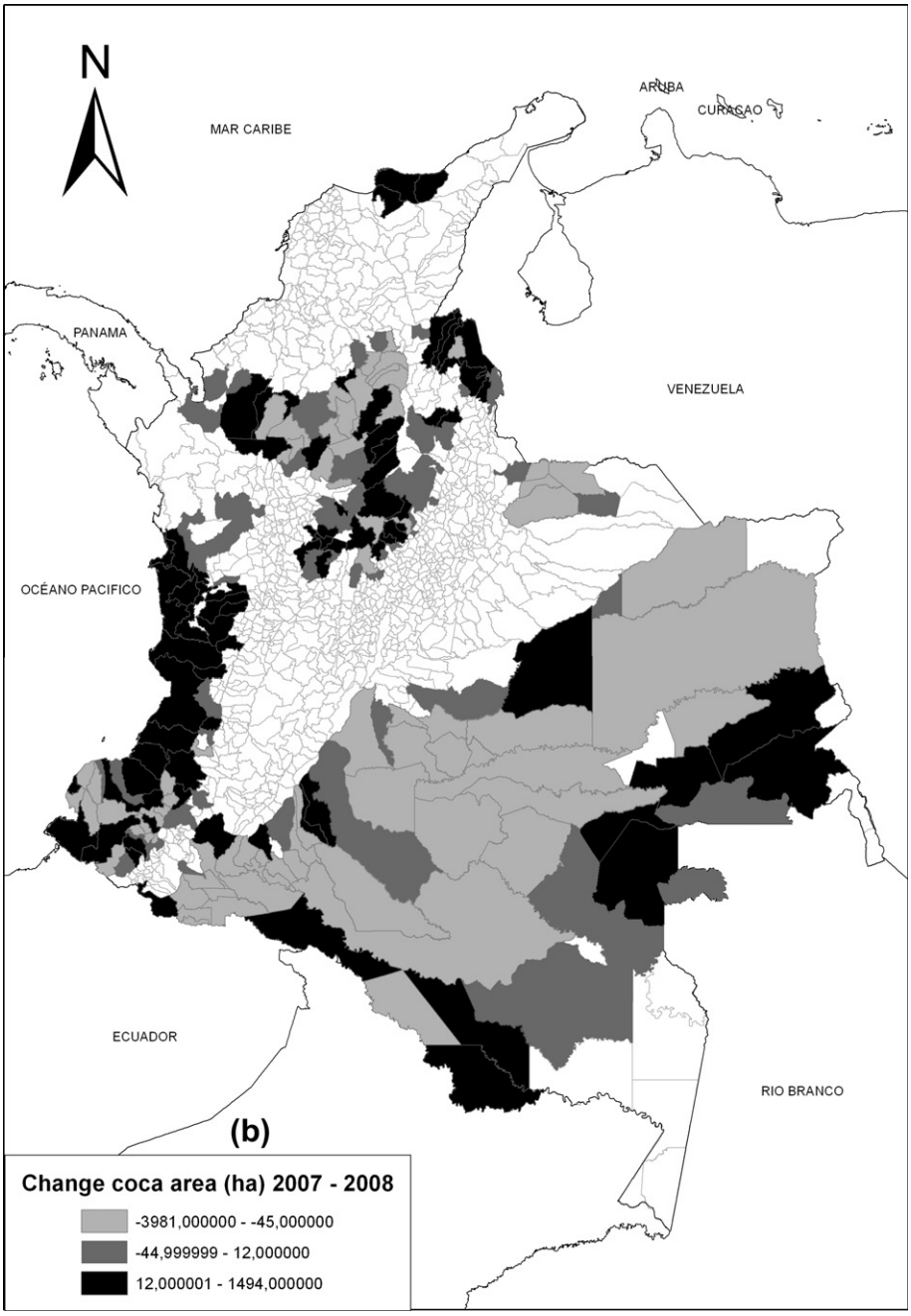


**Map 3.** (*continued*)

**Table 2**
Moran's I – spatial correlation of area fumigated per municipality in year $n$ with area under cultivation in the same municipality in year $n+1$/*Significant correlation (0.05).

| Area sprayed by municipality in the year $n$ | Coca area in the neighborhood municipalities in year $n+1$ | Moran's I |
|---|---|---|
| 2001 | 2002 | 0.105* |
| 2002 | 2003 | 0.102* |
| 2003 | 2004 | 0.217* |
| 2004 | 2005 | 0.192* |
| 2005 | 2006 | 0.121* |
| 2006 | 2007 | 0.235* |
| 2007 | 2008 | 0.179* |

* Correlation is significant at the 0.05 level (2-tailed).

years that each municipality has experienced coca cultivation (minimum 1, maximum 8): many municipalities have seen a continuous production of coca in their territory. In none of the municipalities fumigated during the study period were crops eliminated completely. In fact 81 of the 143 fumigated municipalities show an increasing trend of coca crops.[1]

Our data suggests also that coca plantations go away during fumigation, but come back after the territory stops being fumigated. The evidence is the statistically significant correlation[2] between the size of the area fumigated between 2001 and 2008 and an indicator of variation in coca cultivation, measured as the stan-

[1] The trend was estimated by lineal regression: coca area = $f$ (time).
[2] Pearson Correlation 0.728/significant at the 0.01 level.

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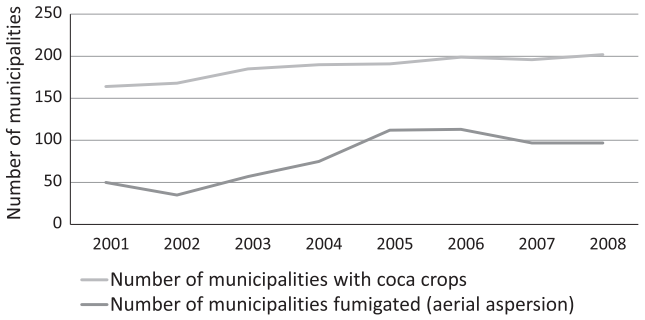
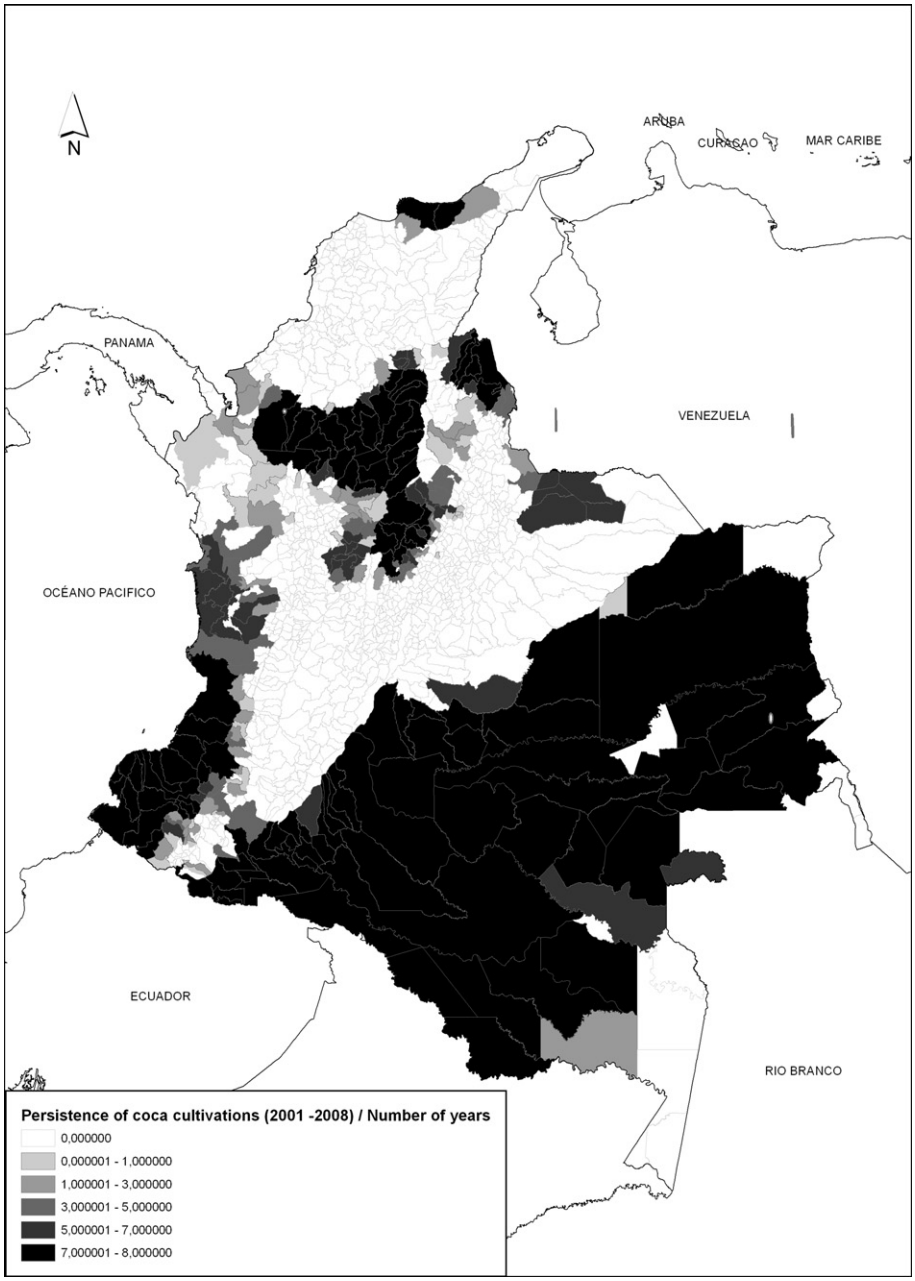



**Fig. 1.** Growth in municipalities with coca cultivations and in municipalities being fumigated (2001–2008).

dard deviation of the area of coca cultivated from the 2001–2008. In other words, the more a municipality is sprayed the more "back and forth" of coca production it experiences.

In conclusion: fumigation is associated with expansion of production to other areas, which can be taken as evidence of displacement. Such displacement diffuses the problem in the territory, with coca production affecting more areas, and presumably more people. Furthermore, production returns, even if at a lower level, to the areas from which it was supposedly eradicated by aerial fumigation. Our local level analysis confirms national and regional level studies, which have claimed that fumigation is not an effective approach in eradicating coca production. Furthermore, in addition to the displacement pattern identified by these studies, we highlight a broader pattern of diffusion.




**Map 4.** Persistence of coca cultivations. Number of years that the municipalities had coca cultivations in the 2001–2008 period.

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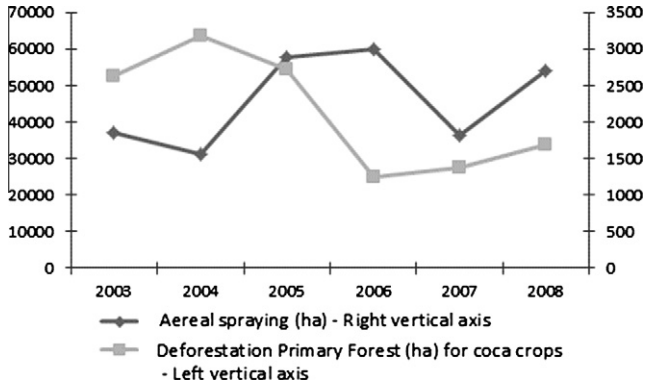


**Fig. 2.** Aerial fumigation (ha sprayed) and deforestation into coca crops in Nariño/Colombia (2001–2008).

### 3.2. Fumigation and deforestation

The official government discourse is one that links fumigation and sustainability, in the sense that more fumigation means less coca production and hence less deforestation. Instead we find that the territorial diffusion of coca activities leads to continued and expanding deforestation, and we attempt to characterize the environmental characteristics of the new areas of the forest affected by coca and fumigations.

On the basis of the crossing of the ecosystem map of Colombia in 2000 and the coca maps (2001–2008) in shape format, we estimated the extent of natural ecosystems (forest) affected by coca diffusion year by year, based upon data on existing ecosystems and natural cover for 2000. Table 3 presents the extents of natural forest affected by coca during the period 2001–2008. At the beginning of the decade, the Amazon and Orinoco region ecosystems were those most affected, but impact upon them has decreased over time: 71,920 ha of coca in 2001 were occupying natural forest in 2000, but in 2008 this area decreased to 22,270 ha. In contrast in 2008 the natural forests of the Caribbean region and especially of the Pacific region, which is considered one of the biodiversity hotspots of the world, showed significant increases in coca conversion. 1982 ha that were natural forests in 2000 in the Pacific became coca cultivations by 2001, and by 2008 this area had increased to 8166 ha.

Even if fumigations had reduced the total area of coca cultivations in Colombia, they have increased deforestation since the balloon effect means that new areas of primary forest are deforested as the war pushes the frontier to new territories. Furthermore, the primary forest that is lost to coca plantations is irreplaceable. Even though fumigation may displace coca, the previous state of the forest is not recoverable. According to the data of SIMCI the displacement of coca crops to new areas has generated a deforestation of primary forest of 110,026 ha between 2001 and 2008.

Our research at Nariño confirms this pattern at the level of a department. About 40% of the area under coca in Nariño in 2008 was natural forest in 2000. Nariño has 10 eco-regions, five of them occupied by coca cultivations; between 2003 and 2008 18%, of the total of deforestation caused by coca in Colombia took place in Nariño. According to SIMCI data, 13,000 ha of natural forest has been converted to coca in Nariño in 2003–2008. 22% of the total area cultivated with coca in 2008 was tropical rain forest in 2000. 8% was riparian forest.

Whereas there is a clear link between coca production and deforestation, this should not be read as an argument in favor of fumigation (and the common replacement by oil palm plantations). Fumigation diffuses and expands deforestation, while an industrial tree plantation is no substitute for primary forest loss. Fig. 2 illustrates the persistence of coca crops and the vicious cycle of fumigation, that characterizes Nariño. An increase in fumigation is associated with a decrease in deforestation (without deforestation disappearing altogether). Nevertheless, when fumigation decreases, the deforestation due to coca cultivation starts increasing again. Interviews with peasants from the area confirm that coca cultivations that had moved to nearby territories return to where they had left from. Rather than an argument for a continuous or intensified fumigation, the point here is that fumigation causes merely spatial displacement and additional destruction, and is ultimately ineffective as a strategy of reduction of coca cultivation. An exception to this pattern of displacement are the last years depicted in Fig. 2 (2007–2008), where despite the increase in fumigation there is an increase also in coca-driven deforestation. A possible explanation is that coca production is no longer displaced to other department but to new municipalities within Nariño itself.

In conclusion: fumigation does not reduce deforestation. It displaces production from areas where the primary forest is already lost biodiversity hotspots where additional primary forest is destroyed.

### 3.3. The effects of fumigation on health and agriculture

The impacts of aerial fumigation on the health of local population and the legal crops are intensely debated in Colombia. Some researchers cannot find statistically significant evidence given that local people usually have contact with many other toxic substances that can cause health effects (such as pesticides and herbicides used on crops) (Varona et al., 2009). Plan Colombia fumigation continues on this basis, the anti-drug police spraying the territory with a mixture of the herbicide 'Roundup Ultra', the proprietary name of a Monsanto product that contains glyphosate and the surfactant polyethoxylated tallowamine (POEA) and 'Cosmo-flux 411F'. In Colombia, pesticides containing glyphosate such as 'Roundup' are registered under the toxicological class IV (slightly toxic) (Nivia, 2001a). The US Environment Protection Agency (EPA) registers glyphosate in Toxicity Category III (with Category I being the most toxic and IV the least). In terms of carcinogenicity it has been placed in Category E, i.e. with evidence of non-carcinogenicity in humans (Sherret, 2005).

Various government sources argue that fumigations have not exceeded health or environmental norms and have not had negative effects, an argument that has been used in favor of the continuation of the policy (United States Department of State, 2010). The Organization of American States (OAS) also published a study in 2005 noting that the chemicals used to aerially eradicate coca did not pose significant risks to humans and most wildlife

**Table 3**
Natural forest in 2000 converted into coca cultivations between 2001 and 2008.

| Natural forest in 2000 converted into coca cultivations between 2001 and 2008 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|
| Amazon and Orinoquian Region | 71,910 | 61,536 | 39,027 | 33,616 | 39,684 | 33,120 | 35,613 | 22,270 |
| Pacific Region | 1982 | 4640 | 4526 | 3821 | 3792 | 2788 | 5839 | 8166 |
| Caribe Region | 3797 | 3352 | 3918 | 3258 | 4039 | 2336 | 6125 | 5712 |

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(Solomon et al., 2005a, 2005b). Similar is the conclusion of the International Narcotics Control Strategy Reports financed by OAS, which also added that the damage from drug crop production and processing far outweighs the negligible risk from exposure to glyphosate due to coca or poppy spraying (Bernal et al., 2009; Bolognesi et al., 2009; Brain and Solomon, 2009; Hewitt et al., 2009).

On the other hand other researchers and NGOs working in the region have provided evidence on the negative impacts of the fumigations on the population's health and the environment (Ávila et al., 2007; Eslava et al., 2007; IDEA, 2005; Nivia, 2001a, 2001b; Walsh et al., 2008a). In several countries "Roundup" was among the first pesticides that was reported to cause human poisoning, and effects reported after exposure include nausea, dizziness, respiratory problems, increased blood pressure and allergic reactions (Nivia, 2001a). And according to the Farm Chemicals Handbook (1990), it is not recommended to use glyphosate via aerial application due to environmental effects. Colombia's fumigations with glyphosate have reportedly generated environmental problems in neighboring Ecuador, as verified by government institutions and scientists (Ávila et al., 2007). Glyphosate has been developed to be applied directly to plant leaves and not through the air (Haney et al., 2000). Similarly (Sherret, 2005) argues that the problem with aerial fumigation in Colombia is not the toxicological profile of glyphosate *per se*, but the open violation of the norms for its application whether through ignorance or intent.

Local communities insist on their experience of the negative impacts of the aerial fumigation, and have denounced the crime perpetrated against them with national-level protests and communiqués (Defensoria del Pueblo, 2007, 2009; La Nación.com.co, 2010; OAIPC, 2010; Oslender, 2010). Studies also of the Institute of Environmental Studies of the National University of Colombia question the results of the OAS studies (Solomon et al., 2005a, 2005b). Of course, such struggle over scientific uncertainty and complexity in an environmental health issue is not unique to fumigation in Colombia, but characteristic of many other environmental controversies. The government continues to deny any link between fumigations and adverse health effects, whereas NGOs call for an application of the "precautionary principle", i.e. a precautionary banning of fumigation given its unknown and disputable, yet highly risky health effects, but in vain (Kennedy and Stefani, 2009).

Health effects are very difficult to verify and this is beyond the purpose of our study. Still, our data confirms a significant correlation between area fumigated and the number of complaints submitted to the Ombudsman and local authorities, a rough indicator of impacts on livelihoods (Table 8). At the beginning of the decade, aerial fumigation was especially concentrated in the department of Putumayo, which received 47% of all aerial fumigation in Colombia (of 224,516 ha sprayed in Colombia between 2001 and 2002, 104,397 ha were in Putumayo). According to our analysis of archives between mid 2001 and mid-2002 the Ombudsman received 318 complaints concerning health impacts or the loss of (legal) crops from aerial fumigation in the three municipalities of Putumayo where 6076 families live. A 2002 study conducted by the health department of Putumayo on the impact of fumigations in community territories showed that 4883 (81.5%) of the 5929 people that had filed complaints reported health problems when interrogated by municipal officials. Furthermore, a 2007 report of the Ombudsman's Office in Putumayo, based on direct observation of the people recovered in the local hospitals, revealed that vomiting and diarrhea, headaches and respiratory problems were common symptoms of those exposed to fumigation. O'Shaughnessy and Branford (2005) documents also negative health effects in the poorer segments of the population, based on field-work in Putumayo. After the increase of claims between 2001 and 2003, there was a decreasing tendency of claims starting in 2004. Our interviews suggest that farmers stopped reporting due to the lack of response by PECIG, the authority overseeing the program of eradication. People no longer believed that the state will attend their claims and complaints. And this may explain why a total of 2559 claims in 2003 were reduced to 781 in 2008. Our field-work and our collection of interviews and photographic material convinced us of the actual impact of fumigations on legal crops, even though we could not conduct proper scientific assessments. Media have also documented with interviews and reports the impacts fumigation in local communities of the Colombian pacific region (TeleSur_TV, 2011, 2011a).

In Nariño, the arrival of aerial fumigation was followed by an increase in formal complaints and claims by the local population. Of the reported claims on the aerial fumigation in the country between 2001 and 2008, 45% came from Nariño and concerned health and crops loss, while at the peak of 2003, 76% of the total claims (1950 claims) were from Nariño (Defensoria del Pueblo, 2007, 2009; Policia Nacional de Colombia – Dirección de Antinarcoticos, 2010). Our analysis of the archive of the complaints shows that between 2000 and 2006, a total of 1177 families reported effects from aerial fumigation including death of domestic animals (ducks, chickens, pigs and cows), pollution and destruction of legal crops used for self-consumption (chiro, chilma, cassava, papacum, chontaduro, banana, coconut, cacao, corn, etc.) and impacts on their health. Indigenous testimonies reported the deaths of three children and two abortion cases between 2000 and 2006 due to the fumigation. CODHES, an organization monitoring human rights and displacement, denounced the death of 25 indigenous children from starvation due to the impact of fumigation on food crops (El Espectador, 2008). During our interviews, indigenous leaders told us that there was no previous consultation or warning about the fumigations and claimed that their water sources have been contaminated and that they have lost seeds and medicinal plants. At the time of writing of this article, indigenous groups continue to denounce publicly the displacement that fumigations cause (Autoridades Indígenas AWÁ – UNIPA, 2011). There is still no evidence of any intervention or assistance from public or private entities as a response to the indigenous claims, despite the repeated denunciations of the terrible impacts (Oslender, 2010; Walsh et al., 2008b).

In conclusion: it is not possible to verify beyond doubt the negative impacts on the health of the people residing in the fumigated areas. There are however serious indications that fumigation affects the health of people and their legal crops. Relevant evidence includes the explosion in the number of formal complaints associated to the fumigations and anecdotal experiential evidence, such as that collected in our interviews with local people and the photographs we took of agricultural crops affected by fumigations.

### 3.4. Aerial fumigation and human displacement

Nariño has been one of the departments of Colombia that has suffered the most in terms of forced human displacement. In 2000 when aerial fumigation started in Nariño, 732 cases of displaced persons were reported, representing a 0.3% of the total in Colombia. But between 2001 and 2008 and as production and fumigations increased so did displacements reaching a total of 31,314 in 2008, corresponding to a 10% of the total of the population displaced in Colombia (301,754).[3]

What is happening in Nariño is part of a broader pattern. Based on our analysis, 70% of the municipalities that experienced

[3] Displacement in Colombia and subsequent migration also had to do with the Pudricion de Cogollo (PC), a disease the oil palm had, and which hit gravely all the farmers that had adopted monoculture palm systems and dedicated less time to subsistence crops.

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increased fumigations between 2001 and 2008 also represent increasing tendencies in forced displacement of the population, as measured by the National Registry on forced population. There is also a significant correlation between fumigated areas and forced displacement for all the years analyzed. In other words, the more the area fumigated in a municipality, the higher the number of people that leaves it.

According to our interviews there are two factors at play: first, part of the population was economically dependent on coca and traditional crops and the destruction of cultivation by the fumigations forced them to move to other municipalities. Second, the aerial fumigation impacted the traditional crops even of those families that were not involved in coca, affecting food security and forcing them to migrate (see also Messina and Delamater (2006) for Putumayo, who documented that fumigation does not affect only areas with coca but also areas with other cultivations). Indigenous and Afro-Colombian communities have denounced the displacement of population from their communities as a consequence of the water contamination, land degradation and loss of food security caused by fumigations (CODHES, 2011; Martinez-Alier et al., 2010; OAIPC, 2010; Oslender, 2010; Solomon et al., 2005a; Walsh et al., 2008a).

The government emphasizes the first driver, i.e. the displacement of coca farmers. From its perspective this is not necessarily a problem, since these are workers who are involved in illegal activities. Furthermore, the government puts blame on other factors and argues that it is not the fumigations that have impacts on the population (Solomon et al., 2005a). and force them to leave The proposition is that displacement is mostly a result of the general armed conflict and the violence of the armed groups and not the fumigations *per se*. Fumigations target the areas where coca and illegal groups presence is strong; according to this narrative, it is not the fumigations that make the people leave but the violence of the coca business and the illegal groups. However other researchers and NGOs (CODHES, 2008, 2009; Ibáñez and Moya, 2007; Ibáñez and Vélez, 2008) suggest that aerial fumigation is directly related and implicated in the armed conflict, and is in many and different ways a cause of displacement in Colombia.

To test the claim of a relation between fumigation and displacement we investigate whether there is a statistically significant correlation between the extent of area fumigated and the number of people displaced. To isolate this from the direct displacement effects of violence, we control for murder rate and violent acts by illegal groups (state-used indicators of violence). In both cases we find a statistically significant correlation (Tables 4 and 5), which confirms that fumigation is associated to displacement independent of the effects of violence. This is not to deny the effect of violence on displacement, only to suggest that fumigation may have a separate effect over and on top of violence. Furthermore formal econometric research along the lines of Angrist and Kugler (2008) could shed more light on the relative weights of the factors that affect displacement and their possible interaction. One possible causal chain that needs to be further interrogated concerns a secondary displacement effect, whereby fumigation in one area causes displacement to a neighboring one, escalation of the violence there, leading to further displacement.

We investigated also whether there remains a correlation between aerial fumigation and displacement after controlling for the number of people actively employed in coca, i.e. to exclude the possibility that a higher displacement is simply the effect of more people working in coca, and being displaced as a result of fumigation destroying the crop. In other words, our goal is to see whether people leave because of fumigation or because coca is eradicated. Since there is no data available on the number of people employed in coca in each municipality, we use the ha of coca cultivated as a proxy for employment. Again, we find a statistically significant correlation, suggesting that fumigation displaces also normal residents, and not only those involved in coca cultivation (Table 6), which is in accordance with what peasants told us in Nariño (see below).

In conclusion there is suggestive evidence that fumigation is associated with increased human displacement, even after taking into account the contribution of violence and the displacement of the labor working in the coca fields.

### 3.5. The uneven effects of fumigation

Is everyone in Colombia affected the same by fumigation and by its side-effects, i.e. displacement and arrival of coca production from the areas that were fumigated?

The first important finding is that the new coca areas where production moves after fumigation tend to be less developed, impover-

**Table 4**
Partial correlation between aerial fumigation (AF) and Forced Displacement of Population (FDP) controlled for violence (number of murders by illegal armed groups – MIAG).

| Control variable | Var 1 | Var 2 | Partial correlation | Value |
|---|---|---|---|---|
| MIAG 2003 | AF 2003 | FDP 2003 | Correlation | 0.075 |
| | | | Significance (2-tailed) | 0.011 |
| MIAG 2004 | AF 2004 | FDP 2004 | Correlation | 0.189 |
| | | | Significance (2-tailed) | 0.000 |
| MIAG 2005 | AF 2005 | FDP 2005 | Correlation | 0.118 |
| | | | Significance (2-tailed) | 0.000 |
| MIAG 2006 | AF 2006 | FDP 2006 | Correlation | 0.131 |
| | | | Significance (2-tailed) | 0.000 |
| MIAG 2007 | AF 2007 | FDP 2007 | Correlation | 0.170 |
| | | | Significance (2-tailed) | 0.000 |
| MIAG 2008 | AF 2008 | FDP 2008 | Correlation | 0.217 |
| | | | Significance (2-tailed) | 0.000 |

**Table 5**
Partial correlation between aerial fumigation (AF) and Forced Displacement of Population (FDP) controlled for violence (number of violent acts by illegal armed groups – VAIA)/there was not statistical significance for 2007.

| Control variable | Var 1 | Var 2 | Partial correlation | Value |
|---|---|---|---|---|
| VAIA 2002 | AF 2002 | FDP 2002 | Correlation | 0.122 |
| | | | Significance (2-tailed) | 0.000 |
| VAIA 2003 | AF 2003 | FDP 2003 | Correlation | −0.019 |
| | | | Significance (2-tailed) | 0.535 |
| VAIA 2004 | AF 2004 | FDP 2004 | Correlation | 0.142 |
| | | | Significance (2-tailed) | 0.000 |
| VAIA 2005 | AF 2005 | FDP 2005 | Correlation | 0.080 |
| | | | Significance (2-tailed) | 0.007 |
| VAIA 2006 | AF 2006 | FDP 2006 | Correlation | 0.073 |
| | | | Significance (2-tailed) | 0.014 |

**Table 6**
Partial correlation between aerial fumigations (AF) and Forced Displacement of Population (FDP) controlled for coca crops area (CA)/there was no statistical significance for 2003 and 2008.

| Control variable | Var 1 | Var 2 | Partial correlation | Value |
|---|---|---|---|---|
| CA 2001 | AF-01 | FDP-01 | Correlation | 0.113 |
| | | | Significance (2-tailed) | 0.001 |
| CA02 | AF-02 | FDP-02 | Correlation | 0.156 |
| | | | Significance (2-tailed) | 0.000 |
| CA04 | AF-03 | FDP-04 | Correlation | 0.190 |
| | | | Significance (2-tailed) | 0.000 |
| CA05 | AF-04 | FDP-05 | Correlation | 0.169 |
| | | | Significance (2-tailed) | 0.000 |
| CA06 | AF-05 | FDP-06 | Correlation | 0.130 |
| | | | Significance (2-tailed) | 0.000 |
| CA07 | AF-06 | FDP-07 | Correlation | 0.077 |
| | | | Significance (2-tailed) | 0.014 |

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ished areas, populated by indigenous and Afro-Colombians. 73% of the municipalities exhibiting an increase in coca cultivation between 2001 and 2008 have a Rural Unsatisfied Basic Needs Index (RUBN) exceeding 50% (generally considered the limit value indicating impoverishment). A second index of impoverishment and public services is the "municipal development index" (IMD): 83% of municipalities that have exhibited increasing coca cultivation between 2001 and 2008 have an index value less than 50.

Our data shows also a statistically significant correlation between coca cultivation and the presence of illegal armed groups, which are typically (though not always) those involved in the coca business, as well as with the remoteness of an area (Table 7; the presence of illegal armed groups is captured in indicators such as the number of violent acts and murders by illegal armed groups). In Nariño 17 people from the Awá indigenous community were massacred in 2009, events that have been covered by the mass media and were reported to us in our interviews with indigenous leaders (ACNUR, 2009; Espectador, 2009).

Coca cultivation is correlated also well with (low) road density and (high) level of natural cover. There is also a statistically-significant and strong inverse correlation between the percentage of the municipal area cultivated with coca and indicators of development (RUBN and IMD) (Table 7). All this suggests a particular geography of the ballooning coca frontier towards remote and impoverished areas where violence is already present (Garcés, 2005), with the possibility of escalating levels of violence after the arrival of coca (Angrist and Kugler, 2008), since the general income hardly increases (Dávalos et al., 2009).

The communities where coca expands, possibly as a result of fumigation, tend to be predominantly indigenous and Afro-Colombian. According to our analysis, during the early 2000s, 7% of the area of coca cultivation was found in indigenous territories, 4% in collective territories of Afro-Colombian communities and 2% in natural parks. By 2008 there is a significant change, as the crops become located mainly in the collective territories of Afro-Colombian communities (36% of the crops). It is estimated that there was

**Table 7**
Pearson's correlations between% municipal area cultivated with coca and other variables associated.

| % Coca crops area/road density 2000 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
| Pearson Correlation | −.093(**) | −.168(**) | −.178(**) | −.174(**) | −.193(**) | −.179(**) | −.193(**) | −.216(**) |
| Sig. (2-tailed) | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *N* | 1125 | 1125 | 1125 | 1125 | 1125 | 1125 | 1125 | 1125 |
| % Coca crops area/municipal development index | | | | | | | | |
| Year | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
| Pearson Correlation | −.101(**) | −.186(**) | −.194(**) | −.190(**) | −.207(**) | −.202(**) | −.235(**) | −.283(**) |
| Sig. (2-tailed) | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *N* | 1102 | 1102 | 1102 | 1102 | 1102 | 1102 | 1102 | 1102 |
| % Coca crops area/forced displacement of population – FDP (number of people) | | | | | | | | |
| Year | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
| Pearson Correlation | .192(**) | .228(**) | .138(**) | .144(**) | .264(**) | .305(**) | .262(**) | .378(**) |
| Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *N* | 1124 | 1124 | 1124 | 1124 | 1124 | 1124 | 1124 | 1124 |
| % Coca crops area/% natural cover 00 | | | | | | | | |
| Year | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
| Pearson Correlation | .109(**) | .256(**) | .246(**) | .220(**) | .261(**) | .238(**) | .254(**) | .316(**) |
| Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *N* | 1124 | 1124 | 1124 | 1124 | 1124 | 1124 | 1124 | 1124 |
| % Coca crops area/rate of Forced displaced of population | | | | | | | | |
| Year | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | |
| Pearson Correlation | .152(**) | .090(**) | .094(**) | .172(**) | .167(**) | .210(**) | .275(**) | |
| Sig. (2-tailed) | 0.000 | 0.003 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | |
| *N* | 1124 | 1124 | 1124 | 1124 | 1124 | 1124 | 1124 | |
| % Coca crops/murders by illegal armed groups | | | | | | | | |
| Year | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | | |
| Pearson Correlation | .119(**) | .108(**) | .328(**) | .286(**) | .289(**) | .259(**) | | |
| Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | |
| *N* | 1124 | 1124 | 1124 | 1124 | 1124 | 1124 | | |
| % Coca crops area/rate murders by illegal armed groups | | | | | | | | |
| Year | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | | |
| Pearson Correlation | 0.030 | .129(**) | .214(**) | .291(**) | .279(**) | .226(**) | | |
| Sig. (2-tailed) | 0.320 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | |
| *N* | 1102 | 1102 | 1102 | 1102 | 1102 | 1102 | | |
| % Coca crops/RUBN 05 | | | | | | | | |
| Year | 2005 | 2006 | 2007 | 2008 | | | | |
| Pearson Correlation | .185(**) | .130(**) | .174(**) | .176(**) | | | | |
| Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | | | | |
| *N* | 1116 | 1116 | 1116 | 1116 | | | | |

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

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**Table 8**
Pearson's correlations between aerial fumigation and other variables associated.

| Aerial spraying/complaints related to impacts by aerial spraying | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
| Pearson Correlation | .661(**) | .507(**) | .301(**) | .294(**) | .567(**) | .287(**) | .402(**) | .510(**) |
| Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *N* | 1124 | 1124 | 1124 | 1124 | 1124 | 1124 | 1124 | 1124 |
| Aerial aspersion/municipal development index | | | | | | | | |
| Year | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
| Pearson Correlation | −.109(**) | −.096(**) | −.122(**) | −.154(**) | −.095(**) | −.185(**) | −.159(**) | −.240(**) |
| Sig. (2-tailed) | 0.000 | 0.001 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 |
| *N* | 1102 | 1102 | 1102 | 1102 | 1102 | 1102 | 1102 | 1102 |
| Aerial aspersion/murders carried out by illegal armed groups | | | | | | | | |
| Year | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | | |
| Pearson Correlation | .110(**) | .151(**) | .140(**) | .365(**) | .347(**) | .258(**) | | |
| Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | |
| *N* | 1124 | 1124 | 1124 | 1124 | 1124 | 1124 | | |
| Aerial aspersion/RUBN 2005 | | | | | | | | |
| Year | 2005 | 2006 | 2007 | 2008 | | | | |
| Pearson Correlation | .066(*) | .131(**) | .124(**) | .153(**) | | | | |
| Sig. (2-tailed) | 0.028 | 0.000 | 0.000 | 0.000 | | | | |
| *N* | 1116 | 1116 | 1116 | 1116 | | | | |
| Aerial aspersion/rural population 2005 | | | | | | | | |
| Year | 2005 | 2006 | 2007 | 2008 | | | | |
| Pearson Correlation | .136(**) | .104(**) | .107(**) | .089(**) | | | | |
| Sig. (2-tailed) | 0.000 | 0.001 | 0.000 | 0.003 | | | | |
| *N* | 1112 | 1112 | 1112 | 1112 | | | | |

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

**Table 9**
Area cultivated with coca in each of the main territorial divisions according to legal status.

| Legal status of the territory | 2000 | 2008 |
|---|---|---|
| Collective territories of Afro-Colombian communities | 3429 | 15,032 |
| Natural National Park | 3877 | 2691 |
| Forest Reserve | 40,919 | 19,007 |
| Indigenous territories | 11,876 | 5636 |
| Subtracted area from forest reserve | 82,909 | 16,450 |

an increase of the areas cultivated with coca in the collective territories of Afro-Colombian communities from 10,231 ha in 2001 to 29,076 ha in 2008. On the other hand the coca area in indigenous territories decreased (according to the official data always) between 2001 and 2008 from 11,791 ha to 6049 ha, but following the general pattern it has spread to new indigenous territories, such as the indigenous territory AWA, which is discussed later.

We do not address here why coca moves to this type of regions. Physical-geographical factors that have to do with forest cover, remoteness vis-à-vis lack of access infrastructure are important, but so are socio-political ones of a historical nature (Hough, 2011), socio-economic and institutional factors (Garcés, 2005; Rangel, 2000; Rocha, 2000; Rubio, 2005) probably related to the low social capital of certain regions (Thoumi, 2005b, 2005c), particularly in those zones where low state capacity and the presence of terror groups prevail (Oslender, 2008).

The same type of statistically significant correlations is observed between fumigation, poverty and remoteness indicators; this makes sense, given that fumigations concentrate to the areas where coca is cultivated and coca cultivation also correlates with these indicators (Table 8). There is therefore an association between the extent an area is fumigated and low levels of rural and municipal development and high levels of rural population. On the other hand, looking at the territorial distribution of coca according to the legal status of a territory, we find that between 2000 and 2008 coca production increased only in collective territories of Afro-Colombian communities (Table 9), which are suffering disproportionately from the effects of the war on drugs (Walsh et al., 2008b), something confirmed also by our in situ observations. Afro-Colombian groups have denounced on several occasions the fumigation policy (OAIPC, 2010), for example in departments such as Nariño (one of the departments with the largest expansion of fumigations in the study period – see Table 10).

A further question is whether there is *intentional* discrimination by the government on its fumigation targets, i.e. whether Afro-Colombian and indigenous areas are more likely to be fumigated than those populated by whites, other factors equal. Our data does not suggest so, since there is no remaining correlation between area fumigated and the area occupied by indigenous territories and Afro-Colombian communities if we control for the extent of coca cultivations in the municipality. In other words, the areas mostly fumigated are those that have the most coca. We confirm together with (O'Shaughnessy and Branford, 2005) that these are areas of poor peasants ("campesinos"), often of indigenous or Afro-Colombian communities, who therefore suffer disproportionately more from the war on drugs, but we do not find evidence of selective targeting. Nonetheless, this is still a "war on the poor", since it is the poor that live in the areas where the coca frontier moves and the ones who suffer the impacts of both the coca trade and the chemicals that are supposed to stop it (O'Shaughnessy and Branford, 2005).

In conclusion: fumigations and coca cultivations are disproportionately concentrated in impoverished areas of peasant, indigenous and Afro-Colombian communities. There is probably no selective fumigation targeting of such communities by the government, but this should not divert us from the basic fact that at the end it is these communities that suffer the most from the indiscriminate chemical "war on drugs".

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**Table 10**
Expansion of the aerial fumigations 2001–2008 in Colombia and Nariño (ha fumigated).

| Aerial Spraying/año | 2000 | 2002 | 2004 | 2006 | 2008 |
|---|---|---|---|---|---|
| Aerial spraying in Colombia (ha) | 58,074 | 130,364 | 136,551 | 171,754 | 133,496 |
| Aerial spraying in Nariño (ha) | 6,442 | 17,962 | 31,307 | 59,865 | 54,050 |
| % of the total area sprayed in Colombia corresponding to Nariño | 11 | 14 | 23 | 35 | 40 |

## 4. Discussion

Why does aerial fumigation fail? Here we follow this body of literature which suggests that centrally managed social plans often misfire, when they impose schematic visions that do violence to complex local interdependencies that are not fully understood (Scott, 1998). Norgaard (1994) for example, investigated the failure of State development programs in the Brazilian Amazon and argued that ecological conditions posed obstacles and huge transaction costs to the development approaches that the Brazilian State imported from other parts of the world. In particular he showed how the productive practices of local groups were well adapted through a historical trial and error process to the ecosystem features of the rainforest, ensuring that small surpluses could be drawn with little transaction costs. Our case-study here, which concerns not a developmental intervention but an "anti-crime" State project of improvement, confirms this thesis of Scott and Norgaard in a very different context. We argue that State policies of fumigation fail to see the particular ecological economy of coca production in the Colombian territory, and hence fail to understand why and how a policy of fumigation is likely to backfire.

The illegal nature of the coca business requires remoteness and ability to hide the plantations. Tropical forests provide ideal environments for growing coca. One reason is that their bio-physical characteristics are favorable to the growth of the crop and to high yields. Equally important however is that access to tropical forests is limited, as it is very difficult to develop road infrastructure there. Their remoteness renders them beyond direct central State control, allowing criminal organizations to hide and avoid persecution (Díaz and Sánchez, 2004; UNODC, 2011). It is therefore the same factors of remoteness vis-à-vis the lack of modern state-based development that render forests both primary biodiversity and conservation hotspots (since human activity has been historically limited) and ideal "habitats" for coca production.[4] From the outset therefore, any policy which has as a result the displacement of production, without being able to control its relocation elsewhere, is likely to cause more deforestation, as illegal groups are likely to move to new patches of remote tropical forest.

For those invested in the coca business, the tropical forests serve multiple functions: stock, shelter and territory (Díaz and Sánchez, 2004; Thoumi, 2005d; UNODC, 2006a). Despite distance from urban areas, the abundance and diversity of hydrological resources and flora and fauna can sustain both production and the daily needs of the armed groups that battle for control over territory for coca cultivation. The tremendous surplus generated by the business makes it possible for the criminal organizations to finance and sustain lavish settlements for themselves (and livable for the workers), even if located very distant from markets. Transport and connection are secured by fluvial or aerial transport (Le Billon, 2001) explains how this peculiar socio-environmental geography of products like coca, which are produced diffusively in the territory (i.e. they are not localized resources, such as mines) and require remoteness, go hand-and-glove with "war-lordism", i.e. armed illegal groups controlling production and engaging in war with the distant central government. From a government perspective, he explains, fighting war-lords in remote jungles requires risky ground engagement. Aerial fumigation emerges then as a riskless war from control centers in the cities, yet, it is one of questionable effectiveness.

Why does coca production move though to poor areas and particularly areas where indigenous and Afro-Colombian groups reside? For historical reasons, which are well covered in other works (Álvarez, 2001; Angrist and Kugler, 2008; Fajardo, 2002; Ibáñez and Moya, 2007; Oslender, 2008; Thoumi, 2005a), the areas where these groups reside are also the least-developed (in economic terms) in the Colombian territory and the most remote. Not only they provide ideal hiding and growing locations and are far from the range of intervention of the military, but also, other factors equal, it is easier for the illegal groups to recruit labor there.

The majority of the labor in coca production is allocated to cultivation. Some of the wage laborers not only cultivate but also process the coca leafs. In addition there is a floating population of day laborers who sell periodically their labor on different parts of the chain depending on seasonal production cycles. Wages are generally higher than wages in the labor market (Ibañez, 2010), although this is not the significant difference. It is the stability and security of income and employment that coca offers that is most appealing to producers. This relative stable profit is tempting enough to compensate for the personal and social disapproval that coca cultivation generates (Ibanez and Carlsson, 2010; Ibañez, 2010). Again, supply-side policies of distant engagement, such as fumigation, do little to change these dynamics. By destroying legal together with illegal crops, they retain coca production as an attractive livelihood option for poor peasants. As more and more people become destitute as a result of the fumigations and the terror of the illegal groups, the supply of mobile coca laborers increases, making coca production more responsive and adaptable to fumigation, labor and production moving back and forth from fumigated areas with more ease.

There are different policy options, more fit to the complex socio-ecology of Colombia's tropical forests and the ecological economy of the coca industry. Ramirez (2011) for example documents how in Putumayo the most effective way of eradicating coca was by hand, rather than by plane. Close engagement reduces the benefits of remoteness and hiding in the tropical forest, whereas it allows a more selective targeting of coca cultivations, without affecting negatively other agricultural activities. A comparative analysis of the relative effects of manual and aerial eradication of coca in Colombia is an important object for further study. Another policy option is the investment in alternative modes of development (or *alternatives to* State-led, Western-type development), responding to the needs of local population, with poverty reduction and development of local public infrastructure (Dion and Russler, 2008). Local development can change the choice domain for peasants, and make coca production an unattractive alternative, reducing the labor supply for the illegal groups and making production more expensive and less profitable. Still, supply-side policies alone are not likely to be effective, as long as there are no policies to curb global demand for processed coca (Laffiteau, 2010). The costs of labor and the production process in general,

[4] Colombia is in the top 12 countries with greatest biodiversity in the world Myers et al. (2000). With a land area of only a 0.7% of the planet's surface, Colombia hosts about 10% of the fauna and flora of the world. Two of the world's most important biodiversity hotspots are in Colombia: the tropical Andes and the Chocó Humid Forests Myers et al. (2000).

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are very small compared to the profits, which in their majority accrue at later stages of the commodity chain, i.e. in trafficking. Demand-side policies are likely to have a much stronger effect on the benefits of the trade than supply-side ones.

Why then is an ineffective policy, this of fumigation, sustained in the presence of better alternatives? This is an important question, but one that is beyond the purposes of this article. Others have studied Colombia's anti-drug policy, in the context of its geopolitical relations with the US and the dynamics of globalized capitalism (Corva, 2008; Crandall, 2008; Guizado, 2006; Thoumi, 2005a, 2005b). Our goal here has been more modest and consisted of developing a spatialized information base for evaluating the impacts of aerial fumigation and informing understandings of why and how the policy has been failing.

## 5. Policy implications and conclusions

This article offered new evidence on the socio-environmental consequences of Colombia's war on drugs, and more specifically, its fumigation policy. Fumigations have diffused the frontier of coca cultivation, expanding deforestation to some of the world's most important biodiversity hotspots. The potential causal link suggested by our research is important: it is not coca production alone that causes the deforestation; it is the fumigation that is continuously pushing it to new areas. More and more people are being displaced, particularly from the more vulnerable segments of the population, including Afro-Colombian descendants. Even if fumigations have been reducing the cultivated area, which is questionable, their goal of total eradication is not feasible; illegal groups have easily adapted and responded to fumigation with fast relocation, forest clearance and production anew. While the intention of the fumigation policy may have been to make coca cultivation too costly to maintain, illegal groups have managed to shift the cost to producers and the local people, maintaining the lucrative cocaine trade going on. The costs of this ineffective war on drugs are disproportionately distributed along lines of class (income), race and ethnicity. Colombia continues to receive massive amounts of US aid to wage this chemical air war on drugs. The policy implications of our study for Colombia and beyond are clear: any government that attempts to stamp out coca production through aerial fumigations should think twice about its effectiveness and its side-effects.

In essence the problem at stake is one of (environmental and social) justice. Whereas the State and the illegal organizations may satisfy some of their purposes with the existing status quo, the local populations and the forest upon which they depend for their livelihood lose. Correcting this grave injustice and ending the ineffective fumigation policy is not easy as there are strong political-economic forces and interests at play that we did not address here. Our goal was more modest and was to reinforce in a more rigorous, integrated and scale-refined manner the documentation of the social and environmental effects of the war on drugs upon people and forests. The hope is that such documentation will contribute to building-up the pressure for a real public debate on the social and environmental costs of the policy, and provide fodder to those who are arguing for alternative approaches and for justice to be given.

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