Collateral damage: The impact of forced eradication of illicit crops on human capital

Daniela Horta Sáenz (Aix-Marseille School of Economics)
Anderson Tami Patiño (Florida International University)

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Policy solutions for illicit crops are highly debatable

- Illicit economies pose significant obstacles for producing countries
  UNODC, 2023
  - Fuel violence and insecurity
  - Exacerbating deforestation
  - Escalate corruption and political instability

- Policy solutions aimed at breaking the negative feedback loop remain vastly opaque.

- Eradication of illicit crops is one policy that has been frequently advocated for and used around the world e.g., Peru, Mexico, Afghanistan, Colombia

- Whether these eradication policies help countries overcome the negative feedback loop is highly doubtful
  - They may exacerbate underdevelopment and create conditions conducive to further illicit crop production (e.g., decreasing human capital)

This paper: Forced eradication in Colombia

Does forced eradication affects human capital and socioeconomic outcomes?

- We investigate this question in Colombia
  - The main producer of coca and supplier of cocaine to the US
  - Aerial spraying of glyphosate has been one of the most important policies
  - The program has been extensively discussed in other countries
- Newly digitize exact polygons of aerial and manual eradication from (2004-2015)
- Combine it with the school census (georeferenced) & population census data (2018)
- We use a sharp RD strategy to causally identify its effects on human capital accumulation and socioeconomic impacts in the medium run

Preview: Forced eradication worsens human capital and living conditions

- Forced eradication diminishes human capital accumulation and educational performance in the short term
- Plausible mechanism: the substantial income shock experienced by families residing in eradication areas
- "Short-term" educational effects have lasting implications in socioeconomic outcomes
  - lower schooling rates
  - increased child labor
  - early marriages
  - deteriorated dwelling conditions

Outline

1. Institutional Background
2. Data
3. Research Design
4. Short run: Human capital results
5. Medium run: Socioeconomic outcomes
6. Conclusions

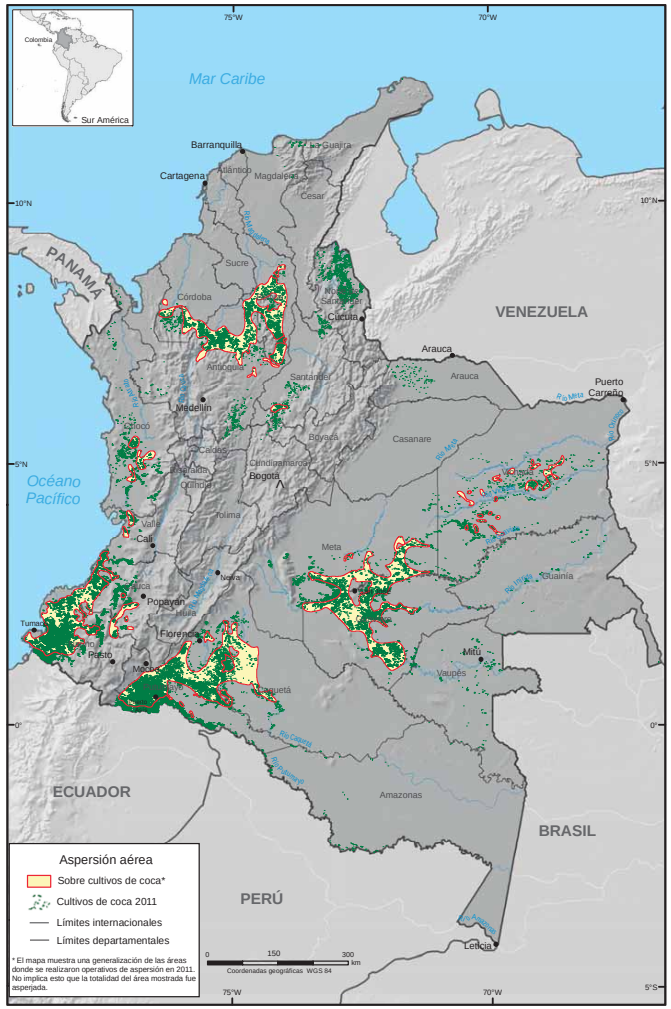
Institutional background: Coca crops and aerial spraying

- Coca has been part of life of indigenous communities in the Andes for centuries
- The main input to produce cocaine
- The only country to implement aerial spraying as a national policy
- Aerial eradication with glyphosate to reduce coca cultivation:
  - 1994-2015
  - Its day to day implementation depends on weather, presence of illegal armed groups, and coca density.

Data

- Maps from 2004-2015 (UNODC)
  - Aerial eradication (2004-2015)
  - Manual eradication (2006-2015)
- School census (C600 form)
  - Dropout, Fail, Transfers
- 2018 Population Census
  - Migration, Level of education, Labor market, Marriage, etc.
- Location of households at the rural section (MGN, 2018)

Mapa 20. Aspersión aérea y cultivos de coca en Colombia, 2011



Fuentes: para cultivos de coca: Gobierno de Colombia - Sistema de monitoreo apoyado por UNODC; para aspersión aérea: DIRAN
Los límites, nombres y títulos usados en este mapa no constituyen reconocimiento o aceptación por parte de las Naciones Unidas

Source: UNODC 2012

Research Design: Regression discontinuity at the school level

Figure: 2004

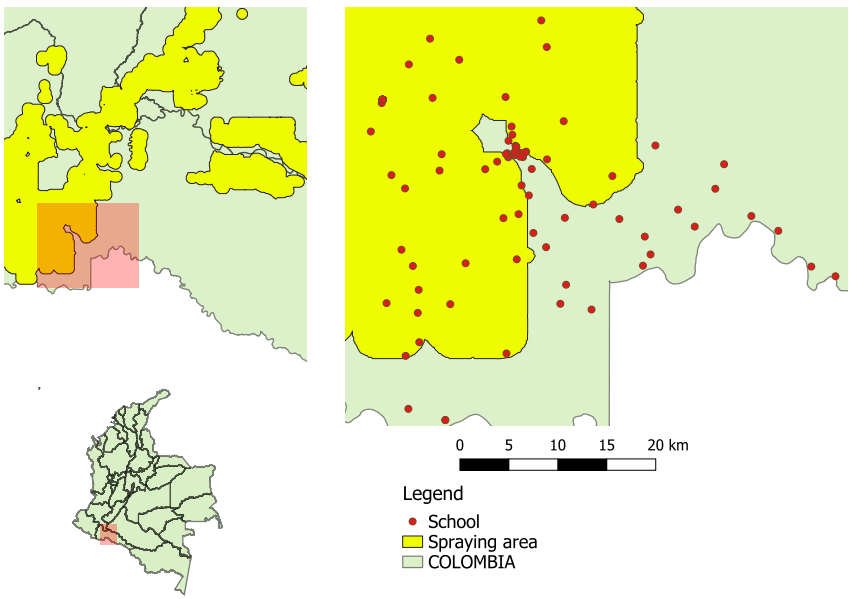
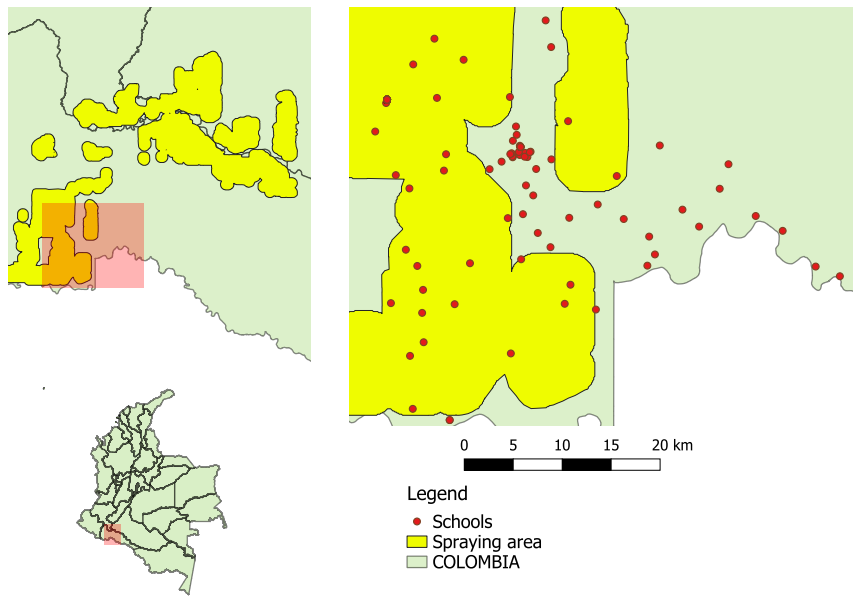
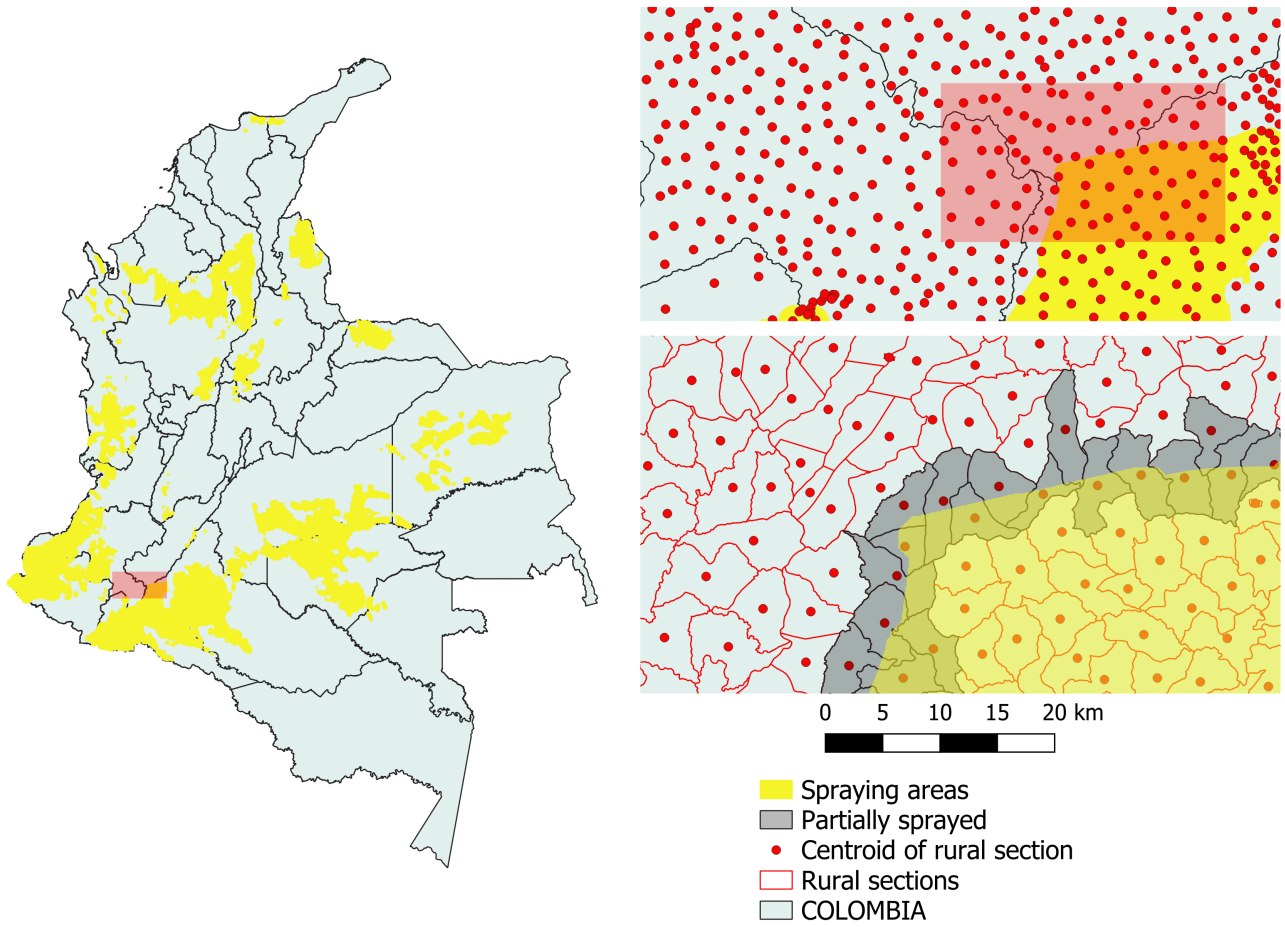


Figure: 2005



Research Design: Regression discontinuity at the rural section level



Note: This map illustrates the areas sprayed between 2004 to 2015 and the rural sections

Regression discontinuity

- We estimate a regression discontinuity model:

$$y_{i,t} = \beta Erad_{i,t} + f(Distance_{i,t}) + X_i + \lambda_t + \epsilon_{i,t} \quad (1)$$

- $Erad_{i,t}$ is a dummy that indicates if a school is inside an eradicated area
- $f(Distance_{i,t})$ is the RD polynomial
- X_i covariates (e.g, geographic characteristics, etc) and λ_t year FE

Aerial eradication worsens educational outcomes

Characteristics of polygons | Assumptions

- Schools located just within the eradication areas experience a 11% higher dropout and 8.5% failure rate compared to schools just outside.

	Dep. var:			
	Dropout rate		Failure rate	
	(1)	(2)	(3)	(4)
Inside sprayed areas	0.00605**	0.0107***	0.00474*	0.00616**
	(0.0030)	(0.0036)	(0.0025)	(0.0026)
Year FE	yes	yes	yes	yes
Baseline controls	no	yes	no	yes
Bandwidth (Kms)	5.93	4.61	9.22	8.68
Mean control	.092	.094	.072	.072
Observations	24640	17216	33825	27406

Note: This table presents the estimated effect of aerial eradication on dropout and failure rate in the following year of eradication (t+1). Base line controls include elevation and a dummy indicating whether the school was inside a sprayed area in the preceding year. All regressions include year fixed effects. Optimal bandwidths are computed using the MSE-minimizing procedure following Cattaneo et al 2019. All regressions include a lineal polynomial and a triangular weighting kernel. Standard errors are clustered at the school level. $*p < 0.1, **p < 0.05, ***p < 0.01$.

Pre school and primary | Gender

The results are robust to ...

- Dropping schools near the border Table
- Refining treatment ($> 80\%$) and control group (0%) Table
- Including geographic controls Table
- Using a quadratic polynomial Table
- Different sample restrictions Figure
- Two-way fixed effects Table

Plausible mechanisms

- **Selective Migration:** coping strategy to escape the negative consequences Plot
- **Conflict:** land mines to deter military presence in the regions Plot
- **Health shock:** adverse effects of herbicides, especially glyphosate, on health outcomes (key determinant of education) Plot
- **Income effect:** substantial shock to the income of the thousands of families Plot

Medium run: Aerial eradication worsens overall schooling

Assumptions

	Dep. var: Schooling rate 25-29	
	Primary	Secondary
	(1)	(2)
Inside sprayed areas	-0.124**	-0.106**
	(0.0606)	(0.0529)
Bandwidth (Kms)	6.09	8.58
Mean control	.910	.535
Observations	1362	2232

Note: All regressions include elevation. Optimal bandwidths are computed using the MSE-minimizing procedure following Cattaneo et al 2019. All regressions include a lineal polynomial and a triangular weighting kernel. Standard errors are clustered at the rural section level. $*p < 0.1, **p < 0.05, ***p < 0.01$.

Other results

- Higher proportion of boys 10-19 years old working
- Higher proportion of girls 10-19 years old in household chores Table
- Lower proportion of girls and women that are single Table
- Again, no effects on health Table
- Again, the mechanism is income: decrease in the proportion of household with access to drinkable water and garbage collection

Conclusions

- Little suggests this strategy will succeed, either in curbing coca supply or reducing violence (Mejia et a. 2017; Reyes 2014 ; Roso 2013)
  Table
- Yet, aerial eradication affects human capital accumulation
- The mechanism seems to be a negative income shock
- Negative effects seem persistent over time: child labor, early marriage, lower schooling levels
- Rethinking the counterproductive measures to destroy drug supply

Thank you

Appendix

Size of polygons and distances

Table: Size of the polygons

Number of spraying polygons	1293
Average area of the spraying polygon. Squared kms	777.25
Average area of the manual eradication polygon. Squared kms	482.92
Average area of municipality. Squared kms	1014.49

Table: Distances schools and households

	Inside		Outside	
	Mean	sd	Mean	sd
Distance from dwelling to nearest school. Kms	2.516	2.668	1.708	2.785
Distance between nearest schools. Kms	1.532	2.076	1.272	1.865

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Aerial eradication doesn't decrease coca cultivation

	Dep. var: Area around 1km from school with coca	
	(1)	(2)
Inside sprayed areas	0.0279	-0.0019
	(0.0292)	(0.0220)
Year FE	yes	yes
Baseline controls	yes	yes
Extended controls	no	yes
Bandwidth (Kms)	5.07	6.08
Bandwidth choice	Optimal	Optimal
Mean control	.349	.331
Observations	16310	16557

Notes: Base line controls include elevation and a dummy indicating whether the school was inside a sprayed area in the preceding year. Extended controls include slope, a dummy indicating whether the school was inside a manual eradication area, and square kms of coca around 1km from the school in the preceding year. All regressions include year fixed effects. All regressions include a lineal polynomial and a triangular weighting kernel. Standard errors are clustered at the school level. $*p < 0.1, **p < 0.05, ***p < 0.01$.

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Identifying assumptions: no discontinuity in other characteristics

- All relevant factors before eradication happened varied smoothly at the spraying boundaries

	Optimal bandwidth				Fixed bandwidth			
	RD Coefficient (1)	SE (2)	BW. (3)	No. (4)	RD Coefficient (5)	SE (6)	BW. (7)	No. (8)
Panel A: Characteristics at the school level								
-Geographic:								
Elevation	62.13527	14.2436***	5.84	24310	62.24343	14.1817***	5.93	24639
Slope	0.02701	0.0544	8.82	32765	0.05014	0.0638	5.93	24634
-Socioeconomic:								
Nighttime light rd 1Km 1993	-0.04493	0.1665	4.06	18712	0.11344	0.1465	5.93	24639
Nighttime light rd 3Km 1993	0.01983	0.1312	3.91	18114	0.14381	0.1132	5.93	24639
Nighttime light rd 5Km 1993	0.01714	0.0959	3.46	16356	0.11242	0.0786	5.93	24639
Landmines rd 1Km 1993	-0.00041	0.0109	6.59	26743	-0.00476	0.0107	5.93	24639
Landmines rd 3Km 1993	0.00380	0.0146	4.99	21790	0.02002	0.0150	5.93	24639
Landmines rd 5Km 1993	-0.00845	0.0197	4.88	21423	0.00909	0.0197	5.93	24639
-Eradication:								
Km2 coca rd 1Km at *t-1*	-0.03967	0.0326	3.24	12781	0.01475	0.0263	5.93	20706
Km2 coca rd 3Km at *t-1*	-0.23418	0.2211	3.59	14236	-0.09498	0.1861	5.93	20706
Km2 coca rd 5Km at *t-1*	-0.67355	0.5226	3.93	15362	-0.56578	0.4555	5.93	20706
Aerial eradication at *t-1*	-0.00232	0.0177	3.28	12946	0.02239	0.0135*	5.93	20706
Manual eradication at *t-1*	0.01407	0.0097	6.50	17090	0.01269	0.0101	5.93	15877
Manual eradication at *t*	0.00901	0.0081	6.83	22127	0.00864	0.0086	5.93	19850

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Stronger effect for pre-school and primary

- An effect driven by children in their initial stages of education, particularly those at the preschool (12 %) and primary school levels (9 %).

	Dep. var:					
	Dropout rate			Failure rate		
	Pre-school	Primary	Secondary	Pre-school	Primary	Secondary
	(1)	(2)	(3)	(4)	(5)	(6)
Inside sprayed areas	0.0113*	0.00848**	0.00246	0.00147	0.00616**	-0.00392
	(0.0059)	(0.0036)	(0.0042)	(0.0025)	(0.0029)	(0.0055)
Year FE	yes	yes	yes	yes	yes	yes
Baseline controls	yes	yes	yes	yes	yes	yes
Bandwidth (Kms)	6.55	5.20	13.5	11.8	8.37	12.2
Mean control	.092	.092	.058	.079	.079	.064
Observations	16104	18009	4224	24348	25623	3923

Note: This table presents the estimated effect of aerial eradication on dropout and failure rate in the following year of eradication (t+1). Base line controls include elevation and a dummy indicating whether the school was inside a sprayed area in the preceding year. All regressions include year fixed effects. Optimal bandwidths are computed using the MSE-minimizing procedure following Cattaneo et al 2019. All regressions include a lineal polynomial and a triangular weighting kernel. Standard errors are clustered at the school level. $*p < 0.1, **p < 0.05, ***p < 0.01$.

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Affect both girls and boys

- We do not observe gender differences in the effect of aerial eradication

	Dep. var:			
	Dropout rate		Failure rate	
	Girls	Boys	Girls	Boys
	(1)	(2)	(3)	(4)
Inside sprayed areas	0.0104***	0.0106***	0.00680***	0.00518*
	(0.0036)	(0.0039)	(0.0026)	(0.0030)
Year FE	yes	yes	yes	yes
Baseline controls	yes	yes	yes	yes
Bandwidth (Kms)	4.93	4.92	9.31	8.32
Mean control	.087	.100	.064	.064
Observations	18120	18138	28661	26612

Note: This table presents the estimated effect of aerial eradication on dropout and failure rate in the following year of eradication (t+1). Base line controls include elevation and a dummy indicating whether the school was inside a sprayed area in the preceding year. All regressions include year fixed effects. Optimal bandwidths are computed using the MSE-minimizing procedure following Cattaneo et al 2019. All regressions include a lineal polynomial and a triangular weighting kernel. Standard errors are clustered at the school level. $*p < 0.1, **p < 0.05, ***p < 0.01$.

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Effect of aerial eradication on education-Donut Hole

	Excluding schools near the border				
	100 mts	200 mts	300 mts	400 mts	500 mts
	(1)	(2)	(3)	(4)	(5)
Panel A: Dropout rate					
Inside sprayed area	0.0110***	0.0114***	0.00607	0.00879**	0.00991**
	(0.0037)	(0.0039)	(0.0042)	(0.0044)	(0.0046)
Year FE	yes	yes	yes	yes	yes
Baseline controls	yes	yes	yes	yes	yes
Bandwidth (Kms)	4.61	4.61	4.61	4.61	4.61
Bandwidth choice	Baseline	Baseline	Baseline	Baseline	Baseline
Mean control	.094	.094	.094	.094	.094
Observations	16832	16405	15914	15503	15085
Panel B: Failure rate					
Inside sprayed area	0.00806***	0.00823***	0.00996***	0.00892***	0.00895***
	(0.0027)	(0.0027)	(0.0029)	(0.0029)	(0.0030)
Year FE	yes	yes	yes	yes	yes
Baseline controls	yes	yes	yes	yes	yes
Bandwidth (Kms)	8.68	8.68	8.68	8.68	8.68
Bandwidth choice	Baseline	Baseline	Baseline	Baseline	Baseline
Mean control	.072	.072	.072	.072	.072
Observations	27022	26594	26103	25692	25274

Note: Base line controls include elevation and a dummy indicating whether the school was inside a sprayed area in the preceding year. We use the optimal bandwidth of baseline results. All regressions include a lineal polynomial and a triangular weighting kernel. Standard errors are clustered at the school level. $*p < 0.1, **p < 0.05, ***p < 0.01$.

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Refining treatment and control definition

	Dep. var:			
	Dropout rate		Failure rate	
	(1)	(2)	(3)	(4)
Inside sprayed area	0.0105*	0.0103*	0.0179***	0.0122***
	(0.0057)	(0.0055)	(0.0045)	(0.0032)
Year FE	yes	yes	yes	yes
Baseline controls	yes	yes	yes	yes
Bandwidth (Kms)	4.41	4.61	4.86	8.68
Bandwidth choice	Optimal	Baseline	Optimal	Baseline
Mean control	.095	.095	.072	.072
Observations	13420	13870	14601	24060

Note: Only schools with more than 80% of the surrounding area falls within a 1 km buffer and schools that are entirely untreated within the same 1 km buffer are included. Base line controls include elevation and a dummy indicating whether the school was inside a sprayed area in the preceding year. All regressions include year fixed effects. All regressions include year fixed effects. Standard errors are clustered at the school level. $*p < 0.1, **p < 0.05, ***p < 0.01$.

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Geographic controls

	Dep. var:			
	Dropout rate		Failure rate	
	(1)	(2)	(3)	(4)
Inside sprayed area	0.00788**	0.00738**	0.00457*	0.00450*
	(0.0037)	(0.0034)	(0.0025)	(0.0025)
Year FE	yes	yes	yes	yes
Baseline controls	yes	yes	yes	yes
Geographic controls	Mun.	Dept.	Mun.	Dept.
Bandwidth (Kms)	4.61	4.61	8.68	8.68
Bandwidth choice	Baseline	Baseline	Baseline	Baseline
Mean control	.094	.094	.072	.072
Observations	17130	17206	27326	27394

Note: Base line controls include elevation and a dummy indicating whether the school was inside a sprayed area in the preceding year. All regressions include year fixed effects. We use the optimal bandwidth of baseline results. All regressions include a lineal polynomial and a triangular weighting kernel. Standard errors are clustered at the school level. $*p < 0.1, **p < 0.05, ***p < 0.01$.

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Quadratic polynomial

	Dep. var:			
	Dropout rate		Failure rate	
	(1)	(2)	(3)	(4)
Inside sprayed area	0.0130***	0.00730**	0.00577*	0.00636**
	(0.0039)	(0.0034)	(0.0033)	(0.0029)
Year FE	yes	yes	yes	yes
Baseline controls	yes	yes	yes	yes
Extended controls	no	yes	no	yes
Polynomial	2	1	2	1
Bandwidth (Kms)	8.32	5.60	10.5	7.30
Mean control	.090	.093	.071	.073
Observations	26629	17699	31367	21776

Note: Base line controls include elevation and a dummy indicating whether the school was inside a sprayed area in the preceding year. All regressions include year fixed effects. We use the optimal bandwidth of baseline results. All regressions include a lineal polynomial and a triangular weighting kernel. Standard errors are clustered at the school level. $*p < 0.1, **p < 0.05, ***p < 0.01$.

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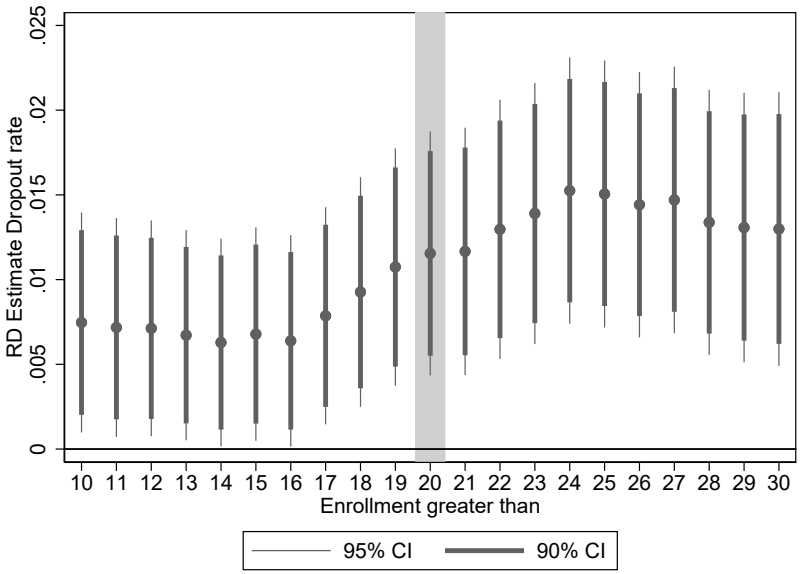
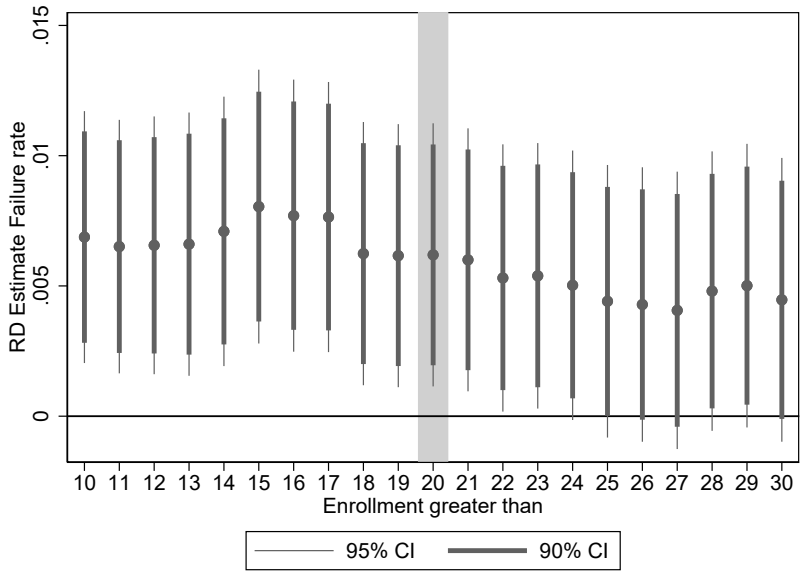
Sample restriction

a) Dropout rate



b) Failure rate



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Two-way fixed effects

	Dep. var:			
	Dropout rate		Failure rate	
	(1)	(2)	(3)	(4)
Inside sprayed area	0.00655***		0.00262*	
	(0.0014)		(0.0014)	
% Sprayed area (5km Radius)		0.00255***		0.00113**
		(0.0005)		(0.0005)
Year FE	yes	yes	yes	yes
School FE	yes	yes	yes	yes
Mean dep. var	.083	.083	.077	.077
Observations	104912	104912	104912	104912

Note: Base line controls include elevation and a dummy indicating whether the school was inside a sprayed area in the preceding year. All regressions include year fixed effects. We use the optimal bandwidth of baseline results. All regressions include a lineal polynomial and a triangular weighting kernel. Standard errors are clustered at the school level. $*p < 0.1, **p < 0.05, ***p < 0.01$.

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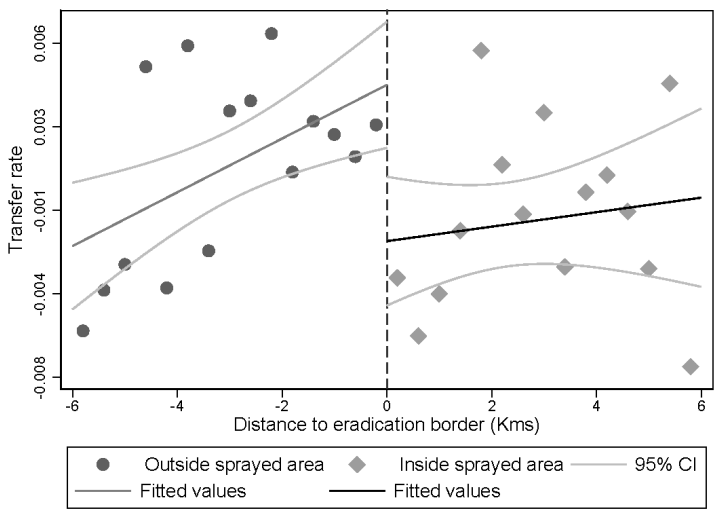
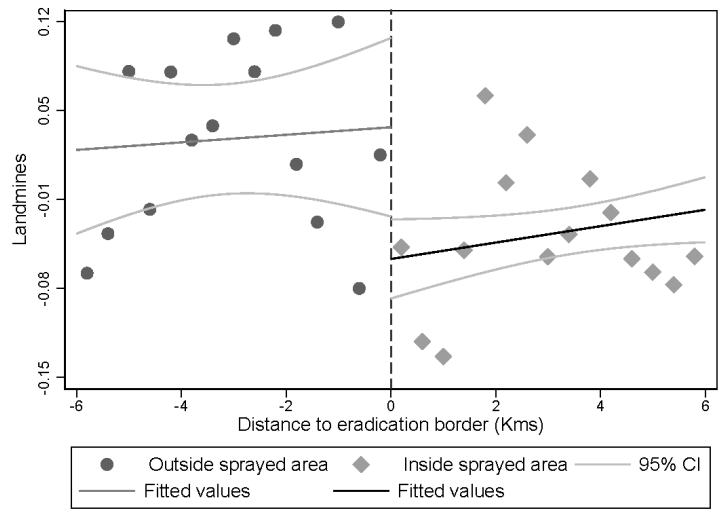
Not evidence of migration or violence channel

- Transfer rates decrease in the treated schools
- Aerial eradication decreases landmine events

a) Transfer rate



b) Landmines (1Km)



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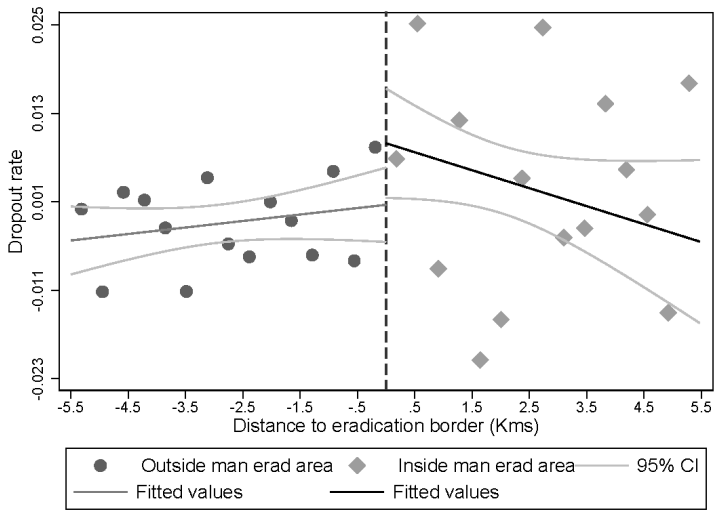
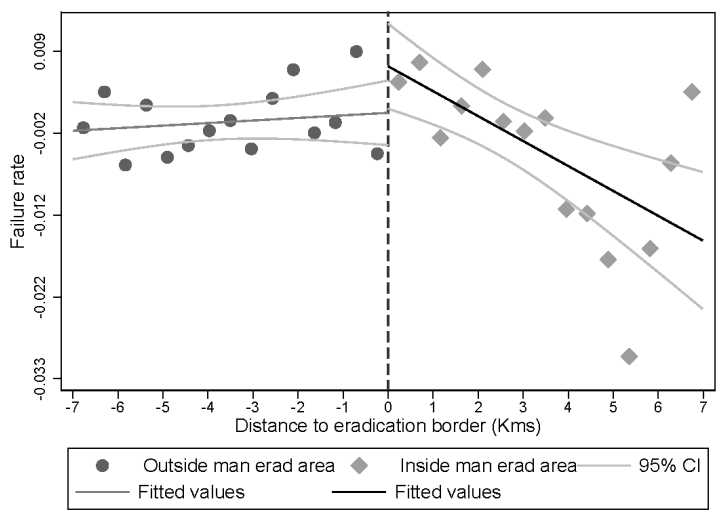
Health channel (manual eradication)

- Manual eradication has only a negative income effect for farmers but does not impact health
- Manual eradication had a similar negative effect on dropout and failure rates

a) Dropout rate



b) Failure rate



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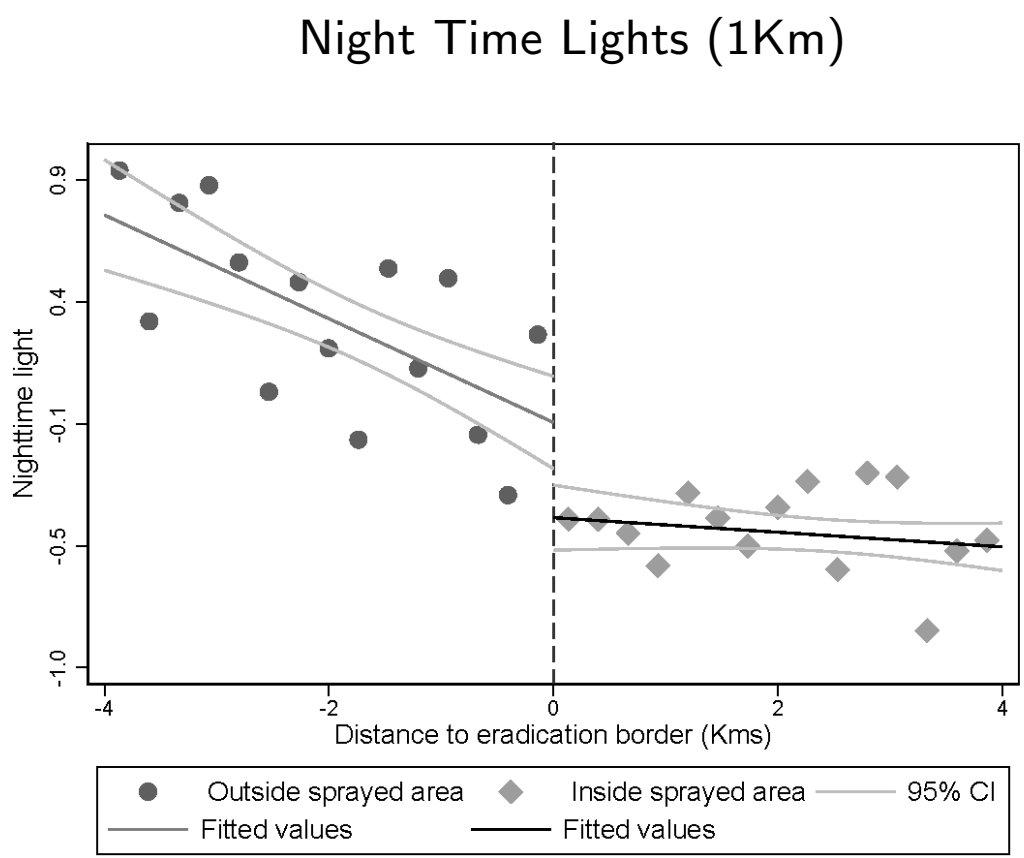
Plausible income shock

- Significant reduction in nighttime light density in areas located just inside the eradication area



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Identifying assumptions: no discontinuity in other characteristics

- All relevant factors before eradication happened varied smoothly at the spraying boundaries

	RD Coefficient (1)	SE (2)	BW. (3)	No. (4)
Panel A: Characteristics of rural sections				
-Geographic:				
Elevation	-180.518	58.339***	10.60	3909
Slope	0.183	0.332	7.14	2343
-Socioeconomic:				
Nighttime light. 1993	-0.252	0.324	7.41	2465
Landmines.1993	-0.008	0.014	15.40	5674
-Coca cultivation:				
Perc of area with coca. 2003	0.001	0.001	5.24	1348
Perc of area with coca. 2016	0.000	0.002	7.32	2417
Panel B: Characteristics with municipality-level data				
-Education:				
School-age population. 1993	0.839	3.201	11.10	3806
Population primary. 1993	1195.823	4310.152	10.20	3482
Population secondary. 1993	978.400	4885.616	10.10	3451
Avg. schooling years. 1993	0.067	0.477	9.34	3077
Illiteracy rate. 1993	-0.250	2.377	7.00	2283
No. teachers. 1996	51.729	452.256	10.20	3637
No. students. 1996	1036	9277	10.10	3603
-Agriculture:				
Suitability index oil palm. 1961-1990.	153.893	671.618	14.40	5308
Suitability index plantain. 1961-1990.	-111.144	490.783	9.18	3287
Suitability index coffee. 1961-1990.	-208.547	378.679	9.67	3501

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Aerial eradication increases early labor market entry for boys and household chores for girls

	Dep. var: Share of children 10 to 19 years old					
	Had a job			Household chores		
	All	Boy	Girl	All	Boy	Girl
	(1)	(2)	(3)	(4)	(5)	(6)
Inside sprayed areas	0.0564***	0.0779***	0.00608	0.0143	-0.0398*	0.0556**
	(0.0198)	(0.0287)	(0.0094)	(0.0258)	(0.0220)	(0.0279)
Bandwidth (Kms)	10.7	10.6	13.5	8.17	6.89	12.5
Mean control	.129	.204	.042	.120	.042	.208
Observations	3304	3087	3882	2380	1769	3594

Note: All regressions include elevation. Optimal bandwidths are computed using the MSE-minimizing procedure following Cattaneo et al. 2019. All regressions include a lineal polynomial and a triangular weighting kernel. Standard errors are clustered at the rural section level. $*p < 0.1, **p < 0.05, ***p < 0.01$.

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Aerial eradication increases early marriage for younger women

	Dep. var: Share of single women			
	10 - 14	15 - 19	20 - 24	25 - 29
	(1)	(2)	(3)	(4)
Inside sprayed areas	-0.0597*	-0.0294	-0.0561^{+}	-0.117**
	(0.0316)	(0.0414)	(0.0381)	(0.0498)
Bandwidth (Kms)	6.89	10.3	11.4	8.04
Mean control	.947	.702	.355	.205
Observations	1582	2570	2740	1730

Note: All regressions include elevation. Optimal bandwidths are computed using the MSE-minimizing procedure following Cattaneo et al. 2019. All regressions include a lineal polynomial and a triangular weighting kernel. Standard errors are clustered at the rural section level. $+p < 0.15 * p < 0.1, ** p < 0.05, *** p < 0.01$.

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No effects on health

	Dep. var: Share of people with health issues			
	All	5 - 9	10 - 14	15 - 19
	(1)	(2)	(3)	(4)
Panel A: Have fallen sick lately				
Inside sprayed areas	0.00638	-0.0320	0.0199	-0.00711
	(0.0125)	(0.0236)	(0.0240)	(0.0143)
Bandwidth (Kms)	6.48	6.73	6.56	9.13
Mean control	.045	.057	.048	.053
Observations	1862	1683	1629	2535
Panel B: With disabilities				
Inside sprayed areas	0.0101	0.00969	0.00378	0.00969
	(0.0073)	(0.0074)	(0.0108)	(0.0154)
Bandwidth (Kms)	8.31	11.7	12.1	8.06
Mean control	.039	.028	.032	.031
Observations	2661	3353	3526	2154

Note: All regressions include elevation. Optimal bandwidths are computed using the MSE-minimizing procedure following Cattaneo et al. 2019. All regressions include a lineal polynomial and a triangular weighting kernel. Standard errors are clustered at the rural section level. $*p < 0.1, **p < 0.05, ***p < 0.01$.

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Negative effects on income

	Dep. var: Share of households with utilities			
	Electricity	Drinkable Water	Sewage	Garbage Collection
	(1)	(2)	(3)	(4)
Inside sprayed areas	-0.0440	-0.119**	-0.0607*	-0.105**
	(0.0378)	(0.0513)	(0.0358)	(0.0528)
Bandwidth (Kms)	10.0	6.73	7.85	6.86
Mean control	.469	.150	.056	.095
Observations	3669	2157	2649	2213

Note: All regressions include elevation. Optimal bandwidths are computed using the MSE-minimizing procedure following Cattaneo et al. 2019. All regressions include a lineal polynomial and a triangular weighting kernel. Standard errors are clustered at the rural section level. $*p < 0.1, **p < 0.05, ***p < 0.01$.

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