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Beyond the Fields: Glyphosate Water Contamination and Infant Health in the US Corn Belt

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Beyond the Fields: Glyphosate Water Contamination and Infant Health in the US Corn Belt

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Introduction

- Glyphosate
 - Most used herbicide globally
 - Sharp increase with the adoption of GM crops
 - Controversial
 - US EPA: No health impacts under current use
 - EU: Strict regulation (1/7000 of US standard in drinking water)
- Limited causal evidence on human health effects

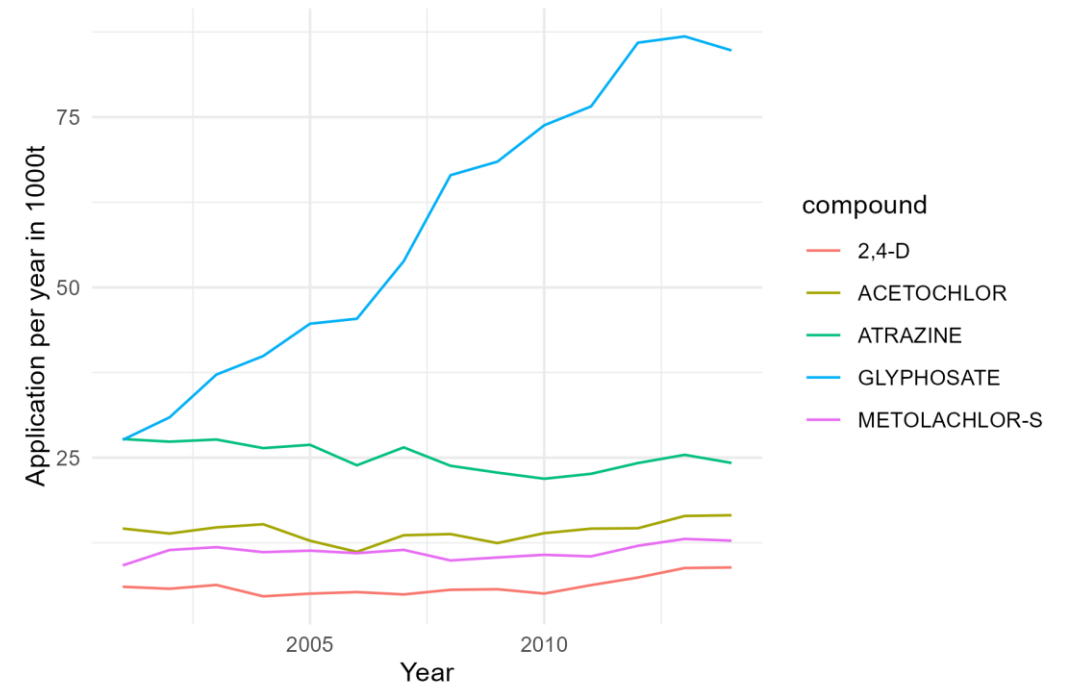


Figure 1. Main pesticide use in the US Corn Belt, 2001-2014.
Source: USGS

Introduction

Study Focus

- Use a quasi-experimental framework to investigate glyphosate's impact on birth outcomes in the corn belt, which accounts for about two-thirds of glyphosate use in the US.

Main findings

- Glyphosate use during the study period leads to 87.6 additional neonatal deaths annually in lower-income areas.
- No observed effects in higher-income areas.

Identification Strategy

Key Issue: Endogeneity

- Following Dias et al. (2023) and Skidmore et al. (2023) to identify glyphosate health effects through water.

Glyphosate Characteristics:

- Transported into water via rainfall (Van Bruggen et al., 2018).
- Detected in water within agricultural basins, especially during application season (Coupe et al., 2012; Battaglin et al., 2014).
- Commonly detected in humans far from applications (Curwin et al., 2007; Ashley-Martin et al., 2023).

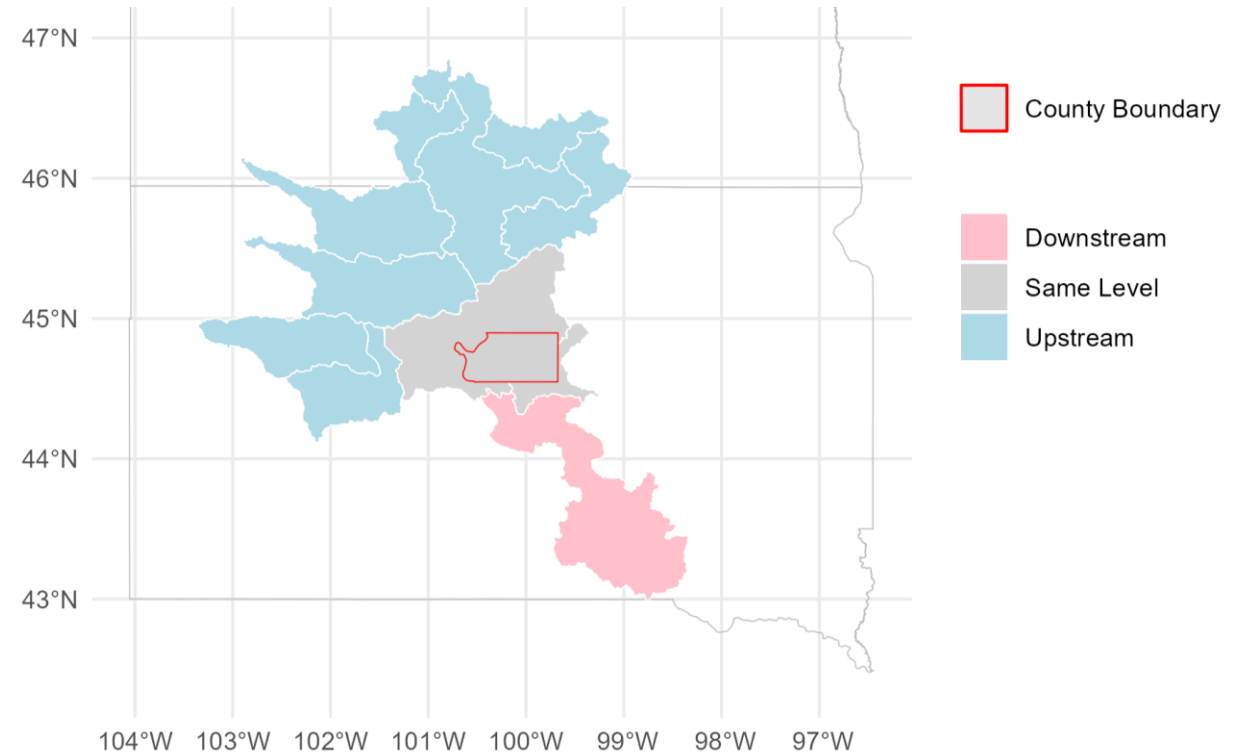


Figure 2: Example of upstream, downstream, and local areas in Sully County, SD.

Empirical Model

Panel DiD model of counties from 2001 to 2014 in the corn belt:

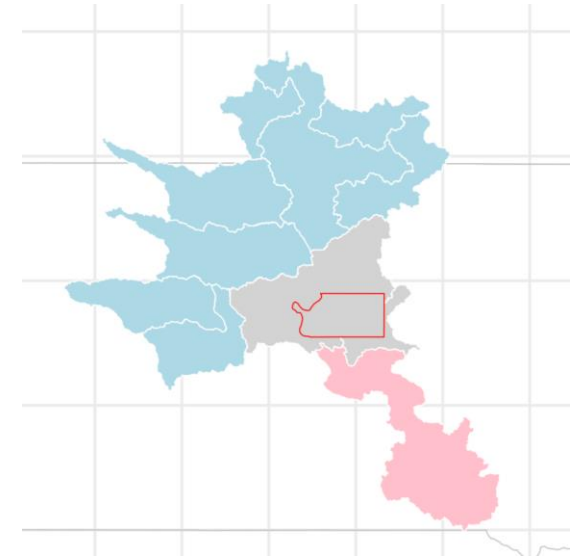
$$Y_{it} = \theta \text{up_gly}_{it} + \mathbf{X}'_{it}\boldsymbol{\beta} + \alpha_i + \delta_{st} + \epsilon_{it}$$

- Y_{it} : Birth outcomes in county i year t , specifically neonatal mortality rate
- up_gly_{it} : Upstream glyphosate use up to 200 km
- X_{it} : Time-varying variables (economic, demographic, industrial water pollution, medical resources)
- α_i : County fixed effects
- δ_{st} : State-year fixed effects
- The regressions are weighted by the average number of newborns in each county.

Data

I compiled data from various sources to construct panel data at county-year level:

- Watershed and water flow: US Geological Survey (USGS),
- Birth outcomes: National Center for Health Statistics (NCHS),
- Glyphosate: USGS,
- Economic data: Bureau of Economic Analysis and Bureau of Labor Statistics,
- Demographic data: NCHS,
- Industrial water pollution: Toxics Release Inventory,
- Medical resources: Health Resources & Services Administration sourced from Griffith et al. (2021),
- Water quality and sources: EPA and USGS,
- Precipitation: PRISM Climate Group.



Descriptive Statistics

	Lower-income mean (1)	Higher-income mean (2)	Diff (3)
<u>Birth outcomes</u>			
Neonatal mortality rate (number of deaths per 100,000 newborns)	329.48	318.17	-11.30
External neonatal mortality rate	1.45	1.13	-0.32
<u>Glyphosate</u>			
Upstream glyphosate (10kg/km ²)	2.35	3.29	0.95
<u>Demographic covariates</u>			
Mother's age	26.10	27.41	1.31
% of mothers with a college degree	17.31	28.83	11.52
% non-hispanic white	89.28	87.76	-1.52
<u>Medical resources</u>			
Hospital beds per capita*1000	2.80	5.11	2.32
Hospital beds density (per km ²)	0.08	0.21	0.13
<u>Water quality</u>			
% using private water sources	31.98	26.28	-5.71

Table 1: Descriptive Statistics for main variables

Main Results

	All counties		Lower-income areas					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Upstream glyphosate	1.847 (3.815)	-2.190 (4.122)	15.08** (6.502)	15.78** (6.091)	15.65*** (5.738)	15.55*** (5.728)	15.95*** (5.763)	15.32*** (5.869)
Upstream glyphosate × income quartile 1		15.49* (8.036)						
Upstream glyphosate × income quartile 2		9.012* (4.841)						
Upstream glyphosate × income quartile 3		3.275 (4.607)						
Local glyphosate	2.983 (3.359)	2.369 (3.303)						1.538 (5.503)
Observations	14,630	14,630	7,770	7,770	7,770	7,770	7,770	7,770
Number of counties	1,045	1,045	555	555	555	555	555	555
Economic covariates	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Demographic covariates	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Industrial pollution covariates	Yes	Yes	No	No	No	Yes	Yes	Yes
Medical resource covariates	Yes	Yes	No	No	No	No	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors clustered at the watershed level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 2: Glyphosate effects on neonatal mortality rate (NMR)

Main Results

- A 10 kg/km² increase in upstream glyphosate use is linked to 15.32 additional neonatal deaths per 100,000 newborns in lower-income areas.
 - This correlates to a 4.6% rise in the neonatal mortality rate.
 - With average 23.46 kg/km² annual glyphosate use and 243,645 births in lower-income Corn Belt areas, glyphosate use during the study period corresponds to 87.6 additional neonatal deaths annually (90% CI: [32.2, 142.9]).

Robustness Checks

- Internal validity: Glyphosate shows no effects on external mortality rate.
- Water contamination glyphosate
 - Glyphosate use in downstream shows no impact on birth outcomes.
 - Glyphosate effects are limited to within 200 km upstream.

Figure 3: External mortality

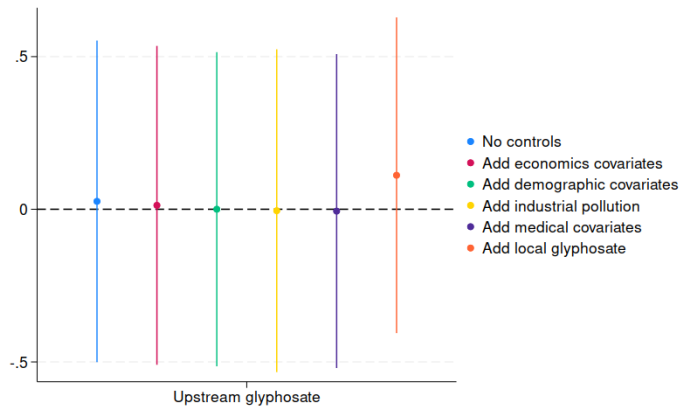


Figure 4: Downstream

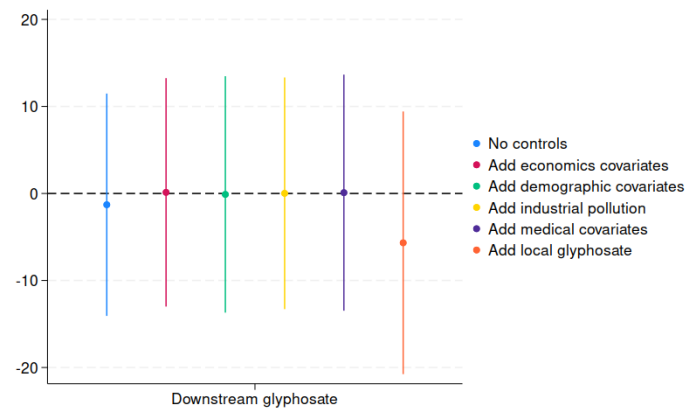
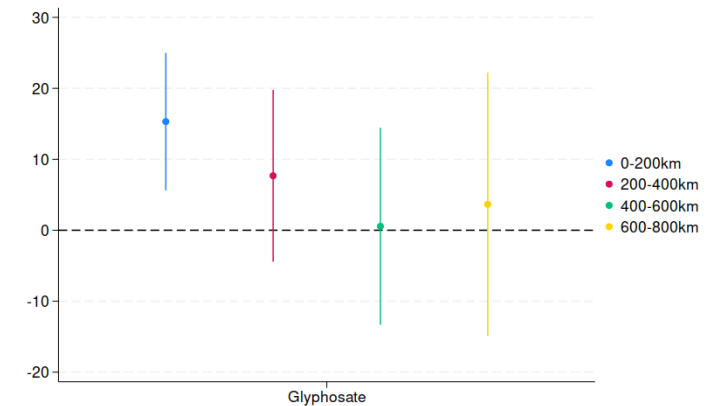
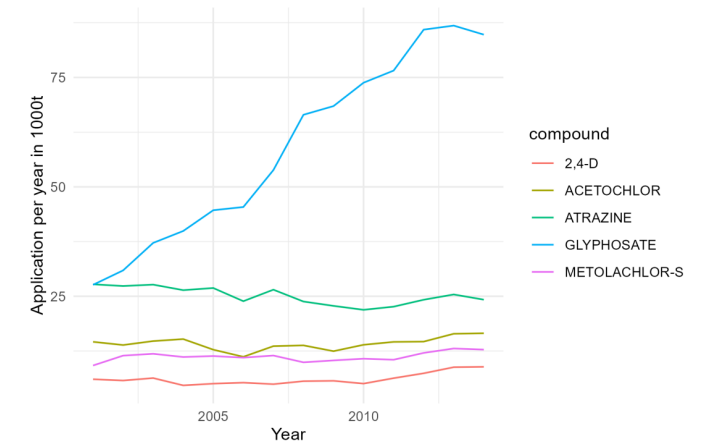


Figure 5: Upstream by distances



Robustness Checks

- Agricultural glyphosate use
 - More significant effects for births conceived during the application season.
 - Higher impacts are observed in counties with higher rainfall during the application season, but not outside the season.
- Glyphosate use unique increased during the study period.
 - The estimates remain robust after controlling for corn and soybean area, other major pesticides, and fertilizers.



Why Glyphosate Only Affects Lower-income Areas?

	Age	Education	Non-Hispanic whites
	(1)	(2)	(3)
Upstream glyphosate	0.124 (3.918)	-3.967 (4.117)	8.852* (5.021)
Quartile 1 × upstream glyphosate	8.489** (4.147)	9.525** (4.427)	-9.009** (4.509)
Quartile 2 × upstream glyphosate	3.683 (3.006)	5.090 (3.640)	-4.854 (4.192)
Quartile 3 × upstream glyphosate	0.714 (2.410)	3.909 (3.298)	-1.249 (3.403)
Observations	14,630	13,370	14,630
Number of counties	1,045	955	1,045
Full controls	Yes	Yes	Yes

Robust standard errors clustered at the watershed level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3: Heterogeneous glyphosate effects on NMR by mother's demographics

Other Heterogeneous Effects and Potential Mechanisms

- Glyphosate's effects are stronger in areas that rely heavily on private water sources.

	(1)
Upstream glyphosate	-0.175 (4.449)
Private water source quartile 2 \times upstream glyphosate	0.807 (4.318)
Private water source quartile 3 \times upstream glyphosate	1.409 (5.574)
Private water source quartile 4 \times upstream glyphosate	9.183 (5.987)
Observations	14,630
Number of counties	1,045
Full controls	Yes
Robust standard errors clustered at the watershed level in parentheses	
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$	

Table 4: Heterogeneous effects on NMR by quartiles of private water source user ratio

Conclusion and Discussion

- A 10 kg/km² increase in glyphosate use leads to a 4.6% rise in neonatal mortality rate in lower-income areas, with no observed effects in higher-income regions.
- Further Research:
 - Explore intermediate channels of impact.
 - Conduct cost-benefit analysis of mitigation strategies.
 - Study health effects across various demographics.

THANK YOU!

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