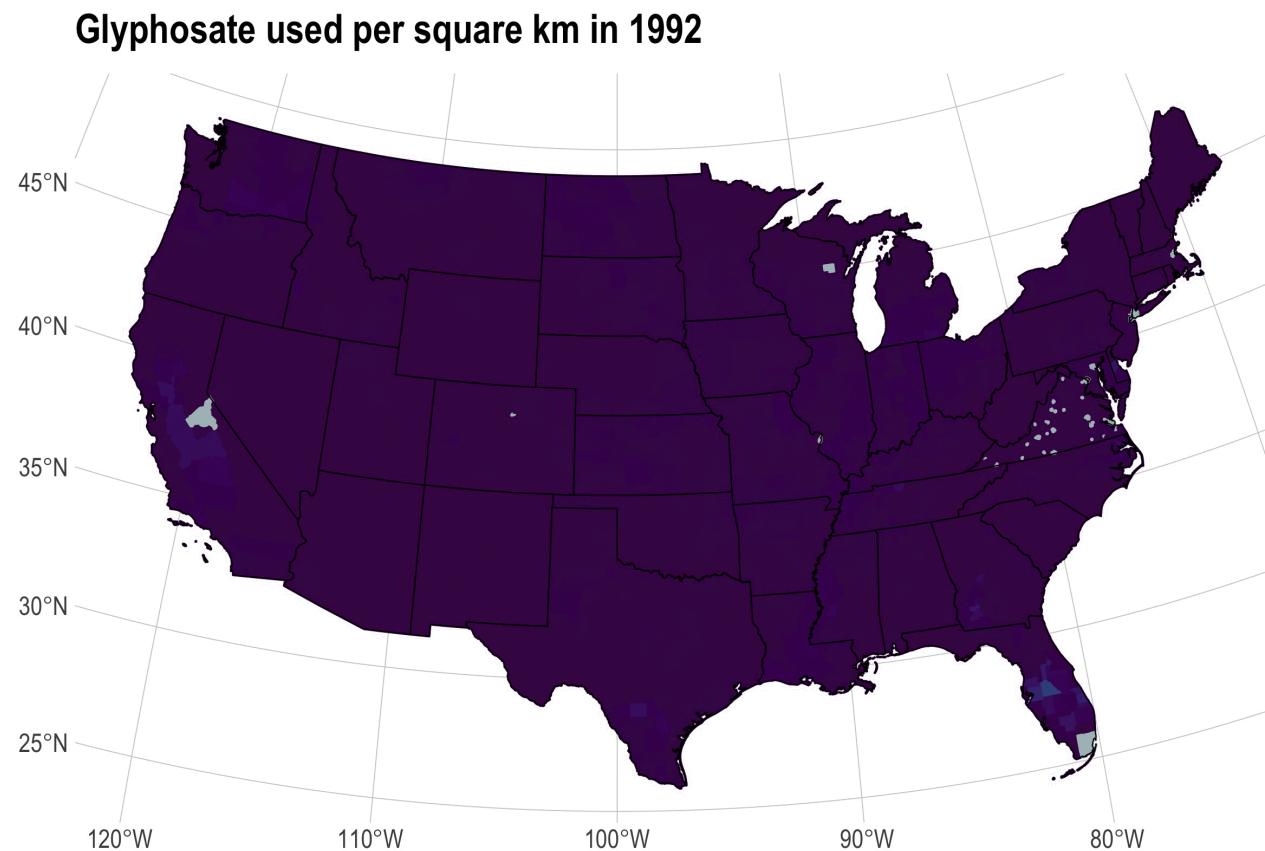


Direct and downstream health effects of pesticides

Evidence from the US rollout of GM crops

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University of Oregon
2022-06-30

Glyphosate in the US



Glyphosate use has increased by **over 16 times** since 1996.

Overview

Research Question Has the adoption of GM crops and glyphosate led to adverse health effects? Are there downstream spillovers?

Methodology Difference-in-differences comparing high and low GM suitability counties before and after the release of GM seeds in 1996.

Data

- County level pesticide use from the USGS
- Micro natality data from the NCHS
- Attainable Yield from the UN-GAEZ

Results High GM yield counties saw large increases in local glyphosate use and decreases in birth weight relative to low GM yield counties, no statistically significant effect from upstream spraying.

Background

GM crops and Glyphosate

- Glyphosate (Round-Up) was released in the 1970's by Monsanto
- Glyphosate is *relatively* non-toxic and water soluble
- Herbicide Tolerant (HT) crops are designed to be resistant to glyphosate
- Can spray fields with glyphosate to kill weeds without harming crops
- HT soy, corn, cotton released commercially in the United States in 1996

Glyphosate and Health

- IARC (part of UN) said glyphosate is likely carcinogenic in 2015
- EPA said glyphosate is safe at relevant doses (*US court just ruled EPA must revisit this designation*)
- Camacho and Mejia (2017) and Dias, Rocha, Reis Soares (2020) show adverse effects on infant health from spraying glyphosate

Methodology

Reduced form effect of GM crops

- (1) How did glyphosate use change
- (2) How does birth weight change

in high vs low GM suitability counties, before and after 1996.

$$y_{ijt} = \alpha_j + \lambda_t + X'_{jt}\delta + \sum_{\tau \neq 1995} \gamma_\tau^l D_{j\tau}^l + \gamma_\tau^u D_{j\tau}^u + \varepsilon_{ijt}$$

Important: Effect is calculated *relative* to whatever was going on in the pre-period (supposedly more toxic chemicals, more tilling)

Parallel trends required for causality

If genetically modified crops had not been released, then the difference in (1) glyphosate use and (2) infant health between high and low GM suitability counties would have remained constant.

Two Stage Least Squares

The first stage effect of treatment on glyphosate use can be an instrument to estimate the causal effect of glyphosate (relative to old pesticide regime).

$$G_{jt} = \alpha_j + \lambda_t + X'_{jt}\delta + \sum_{\tau \neq 1995} \gamma_\tau^l D_{j\tau}^l + \gamma_\tau^u D_{j\tau}^u + u_{jt}$$

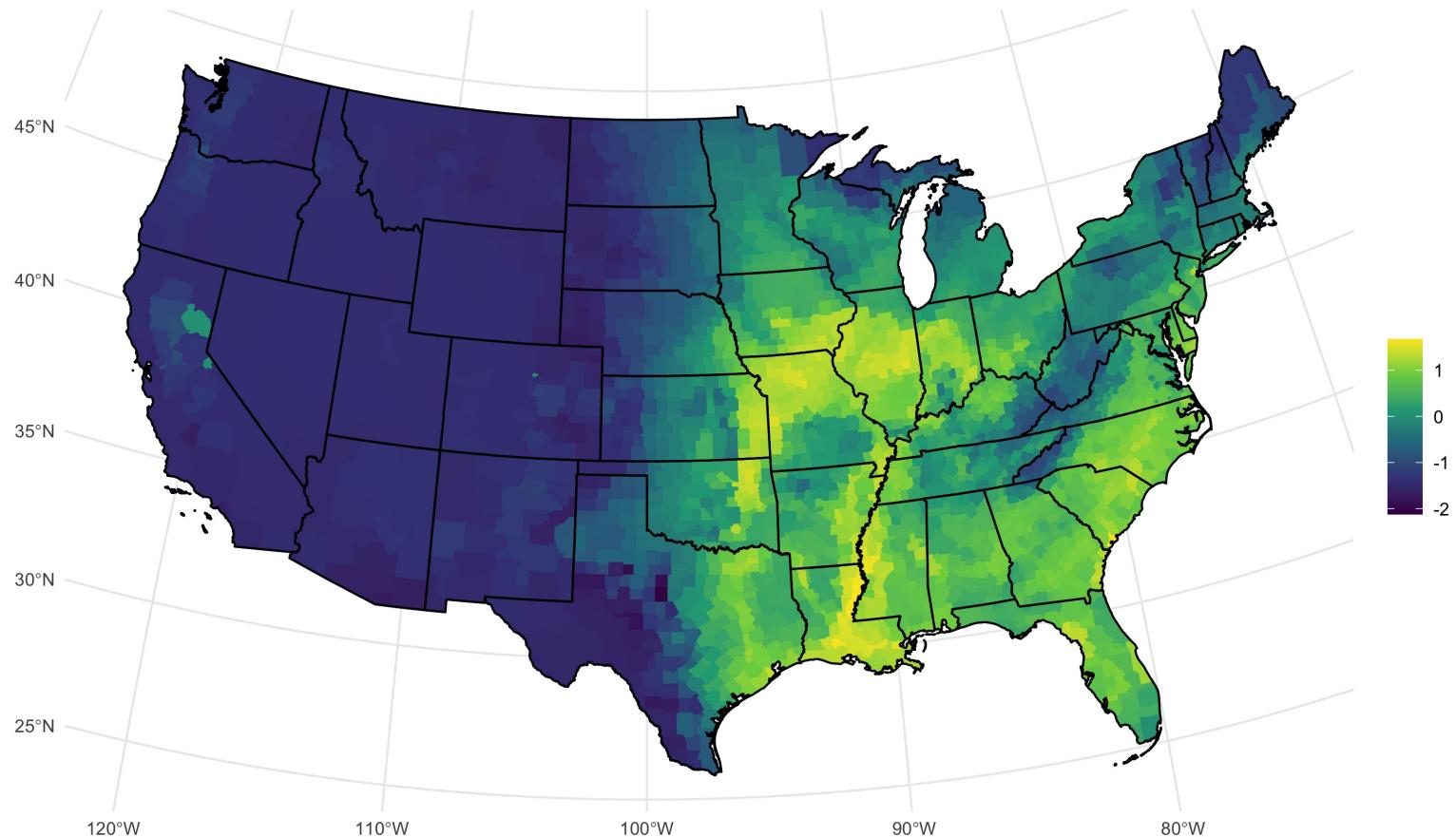
$$y_{ijt} = \beta \hat{G}_{jt} + X'_{jt}\eta + \alpha_j + \lambda_t + \epsilon_{ijt}$$

Exclusion restriction required for causality

Our instruments (treatment D_{jt} interacted with years since 1995) only affect infant health outcomes through glyphosate, conditional on year and county fixed effects.

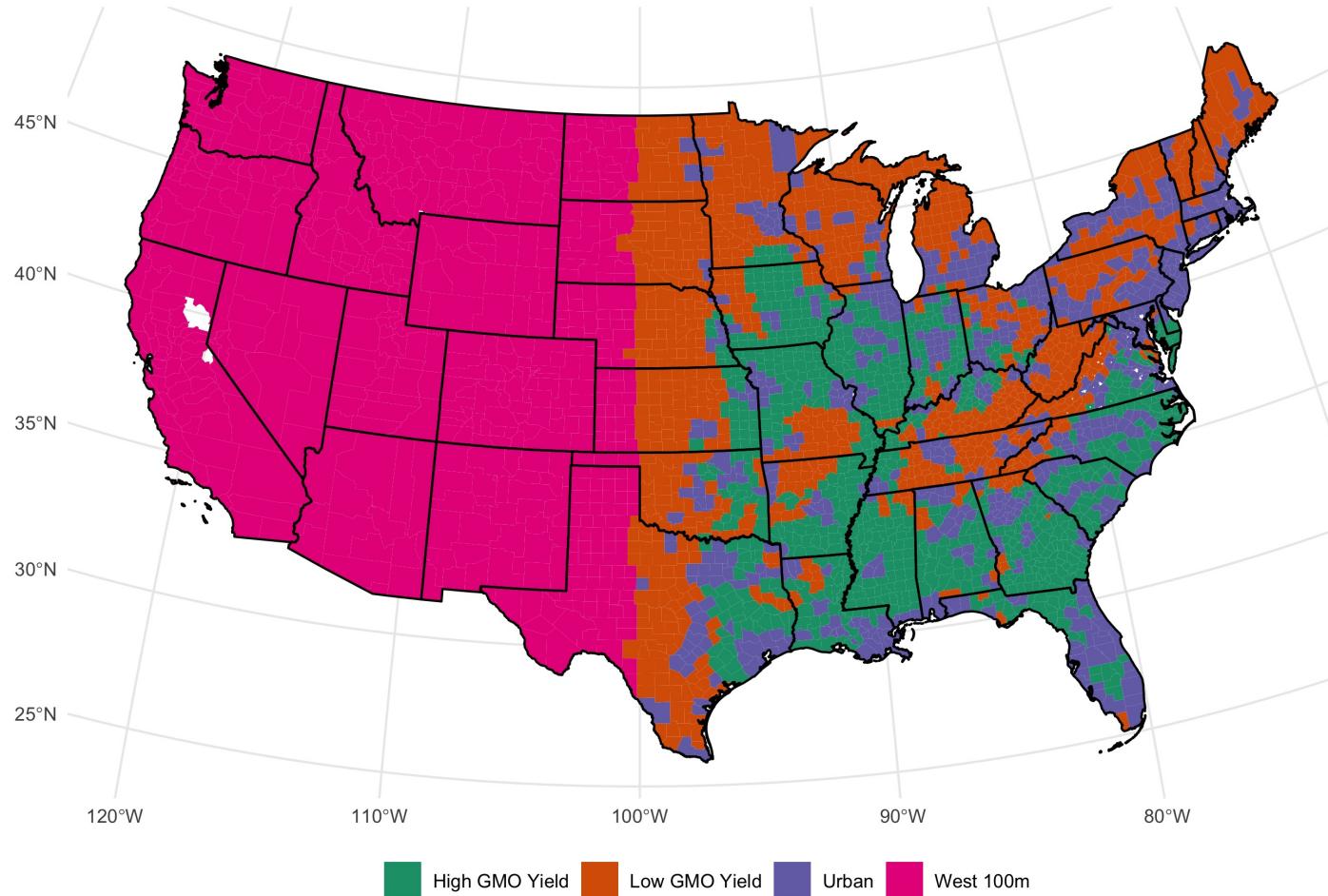
GAEZ Attainable Yield

We take the difference between "High" and "Low" input to focus on counties that have the most to gain from switching to GM crops.



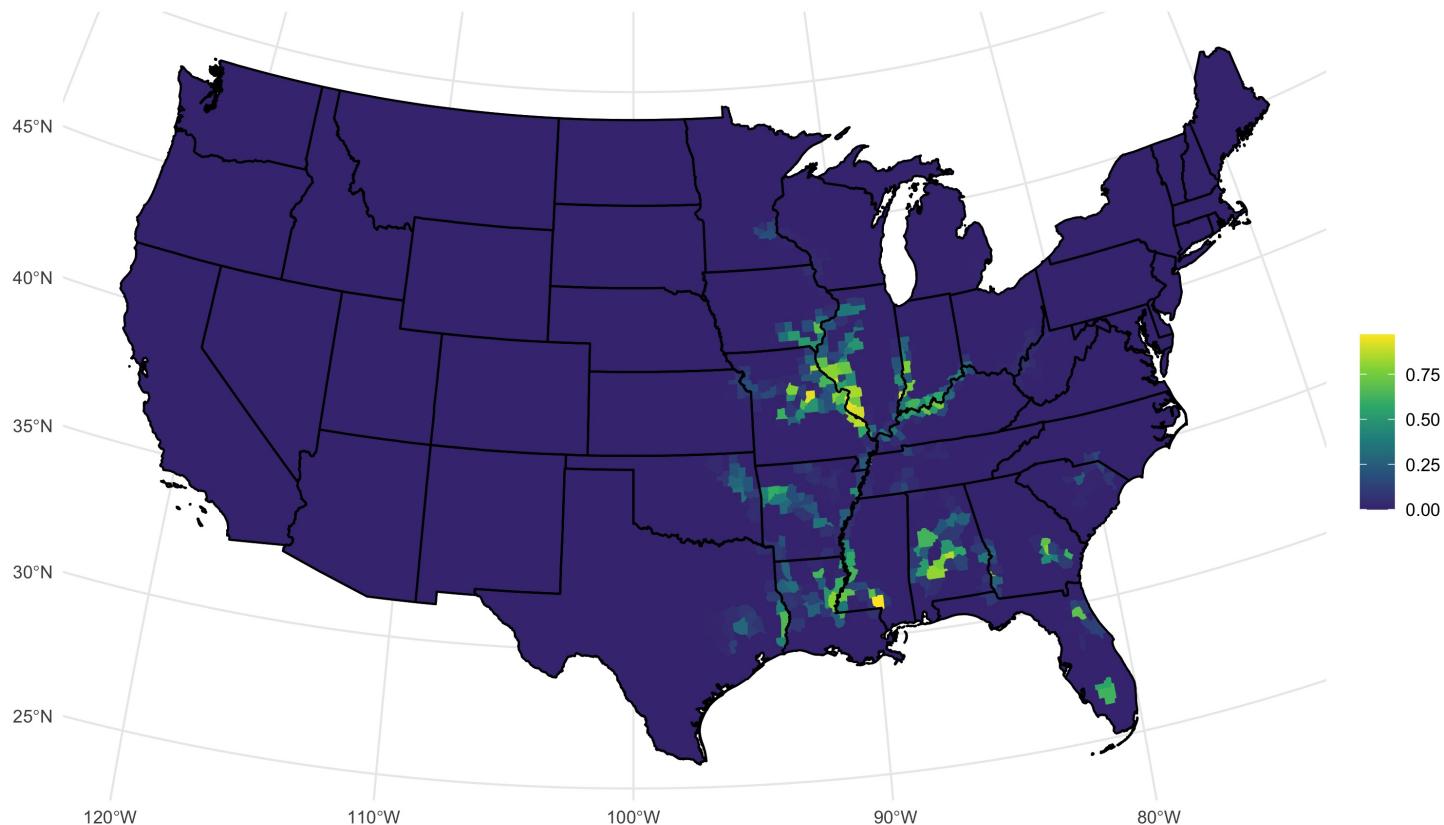
Assigning treatment

Eastern, rural counties above median attainable yield are "treated"



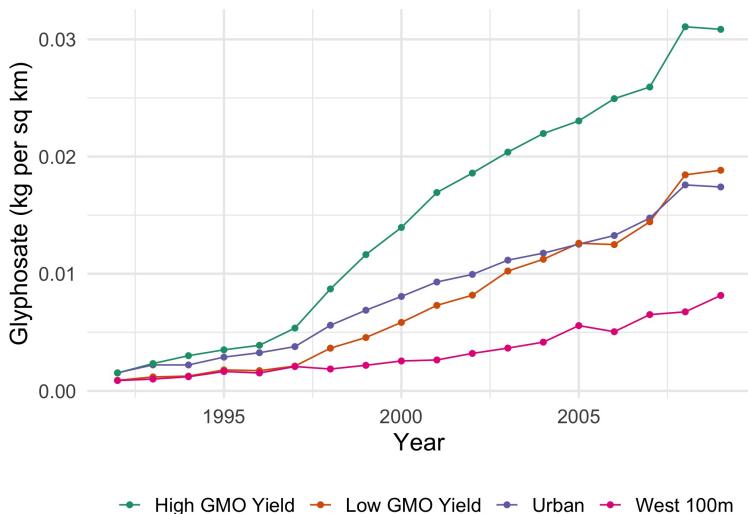
Aggregating Upstream Treatment

Proportion of upstream counties that are treated

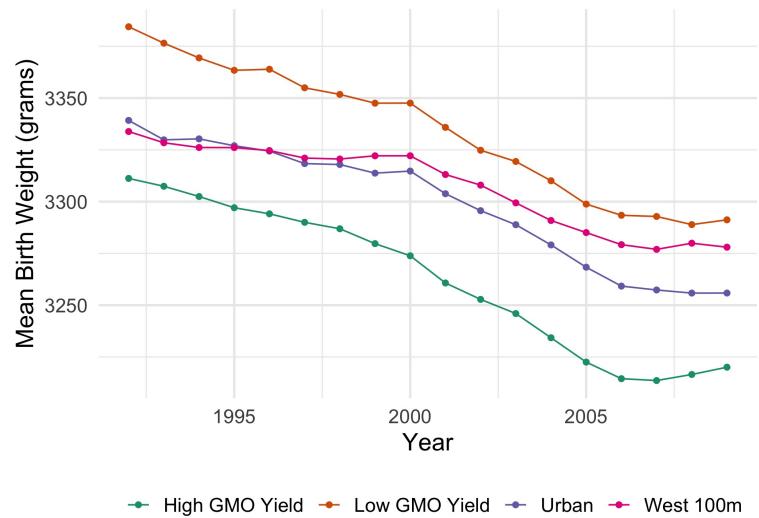


Trends in glyphosate and births

Glyphosate



Median birth weight

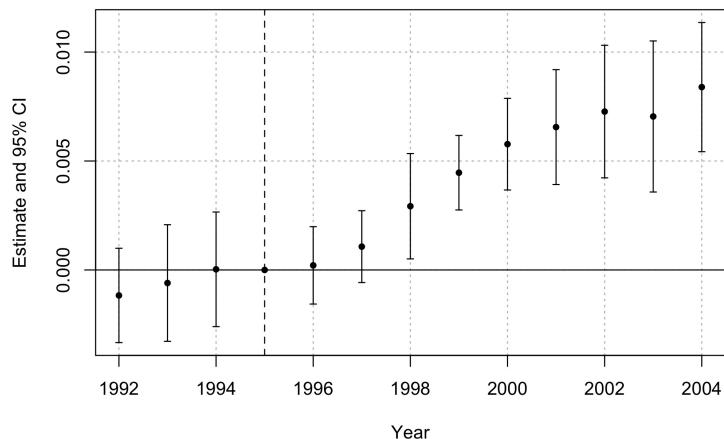


Results

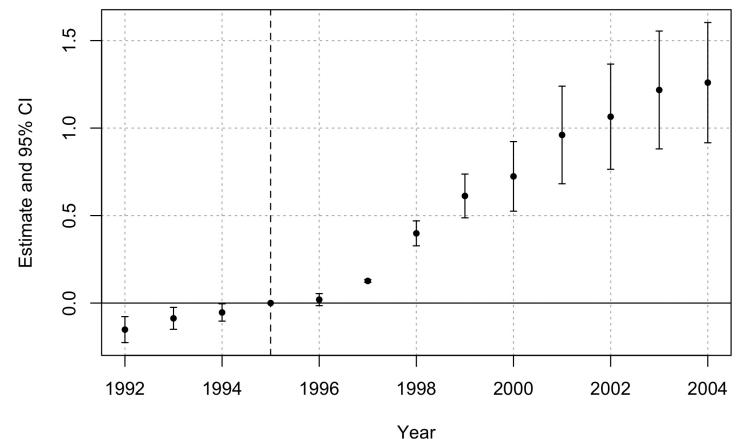
First stage effect on glyphosate

The effect of high GM yield on...

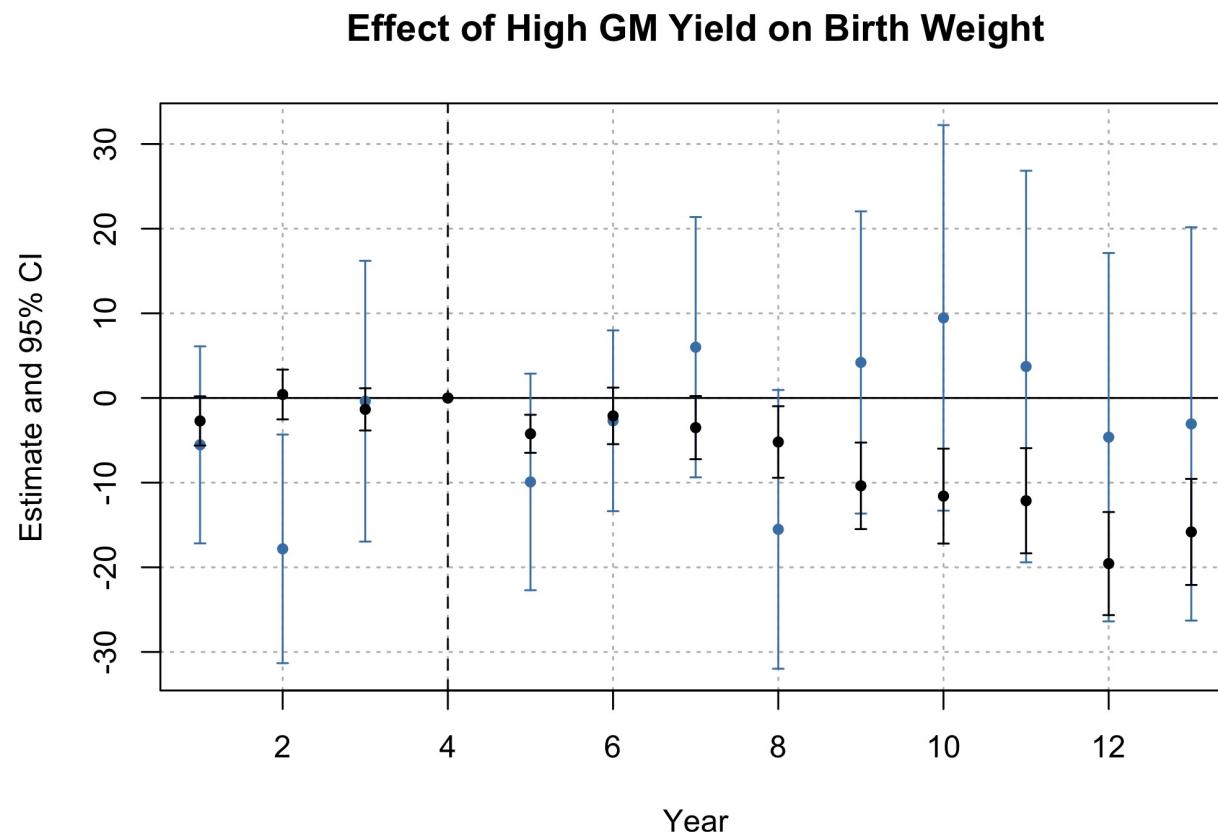
Local Glyphosate



Upstream Glyphosate



Reduced form effect on birth weight



For **local** treatment and the **proportion upstream** that are treated

TSLS estimates

Effect of Glyphosate on Birth Weight

| | 1 | 2 | 3 |
|---|---------|---------|---------|
| Glyph per sq-km | -1000* | -1221** | -1303+ |
| | (388) | (394) | (601) |
| N | 5383402 | 5037287 | 5383402 |
| Mother Controls | | X | |
| Herbicide Controls | | | X |
| F-Stat | 37150 | 34871 | 23641 |
| + p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001 | | | |

Moving from the 50th to 90th percentile in glyphosate use in 2004 leads to a **43 gram decrease** in birth weights.

Conclusion

Evidence of adverse health effects from glyphosate

- Birth weights decrease in high GM suitability counties relative to low GM suitability counties after release of GM seeds in 1996
- Results are robust to various specifications of treatment

Implications for policy

- Results suggest we use more glyphosate than is socially optimal
- But the net effect on welfare of regulation depends on many factors

Thank you

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Appendix

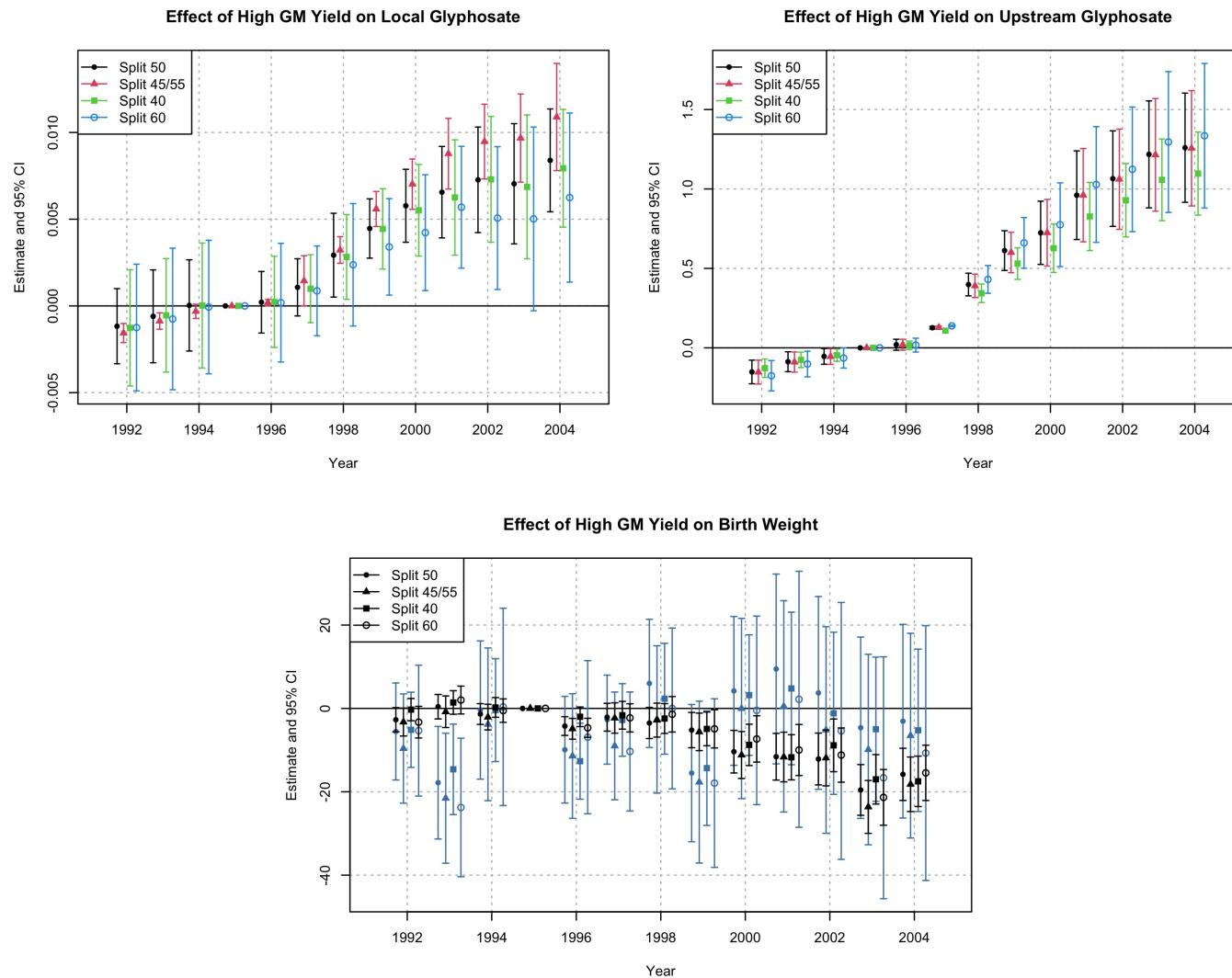
Balance table

| Variable | High GM Yield | | Low GM Yield | | Urban | | West 100m | |
|------------------------------------|---------------|--------|--------------|--------|---------|---------|-----------|---------|
| | Mean | Sd | Mean | Sd | Mean | Sd | Mean | Sd |
| Number of Counties | 838 | 0 | 935 | 0 | 799 | 0 | 488 | 0 |
| Birth Weight (g) | 3345.69 | 81.89 | 3407.69 | 72.02 | 3386.99 | 59.69 | 3354.3 | 101.83 |
| Pct Low Birth Weight | 7.91 | 2.17 | 6.2 | 1.7 | 6.91 | 1.44 | 6.38 | 2.36 |
| Percent Male | 51.11 | 1.85 | 51.19 | 2.41 | 51.26 | 0.9 | 51.53 | 3.38 |
| Infant Mortality | 3.71 | 3.26 | 3.39 | 5.37 | 5.88 | 6.83 | 3.31 | 3.65 |
| Total Births | 346.85 | 286.17 | 301.63 | 300.42 | 3765.97 | 9079.14 | 328.33 | 1516.54 |
| Glyphosate (g/km ²) | 2.59 | 3.09 | 1.29 | 1.46 | 2.25 | 3.72 | 1.05 | 1.49 |
| Total Crop Area (km ²) | 354.49 | 414.88 | 351.65 | 490.9 | 243.35 | 386.54 | 337.28 | 478.71 |
| Total Pop (1000's) | 25.26 | 19.37 | 24.01 | 23.11 | 241.71 | 485.73 | 17.65 | 22.76 |
| Percent Hispanic | 1.39 | 2.81 | 3.32 | 11.31 | 5.25 | 10.07 | 12.42 | 17.54 |
| Unemployment Rate | 7.04 | 2.57 | 6.78 | 3.49 | 5.95 | 2.43 | 6.7 | 4.06 |
| Pct Some HS Degree | 35.95 | 8.91 | 32.86 | 10.49 | 24.99 | 8.22 | 25.48 | 8.83 |
| Pct HS Degree | 35.43 | 5.9 | 35.86 | 6.16 | 32.64 | 6.15 | 32.86 | 4.87 |
| Pct Some College | 18.32 | 4.29 | 19.8 | 5.26 | 24.46 | 5.12 | 26.98 | 5.07 |
| Pct College Degree | 10.3 | 3.58 | 11.48 | 4.64 | 17.92 | 7.83 | 14.68 | 5.72 |
| Income per Capita | 16.38 | 2.18 | 16.82 | 2.73 | 20.79 | 4.18 | 17.76 | 3.89 |

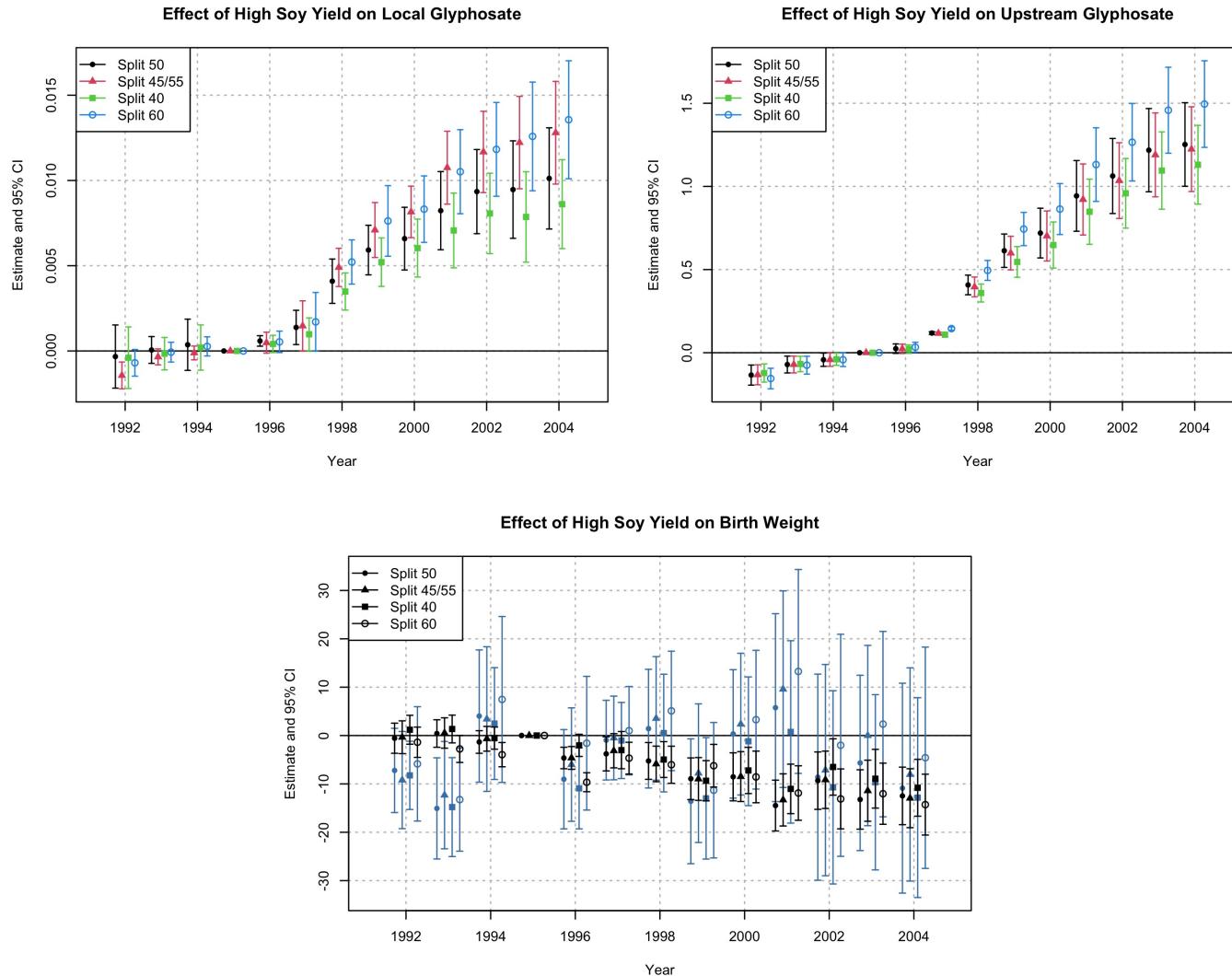
Means and standard deviations are calculated on county level averages between 1992 and 1995, which is the period prior to the release of GM crops.

Robustness

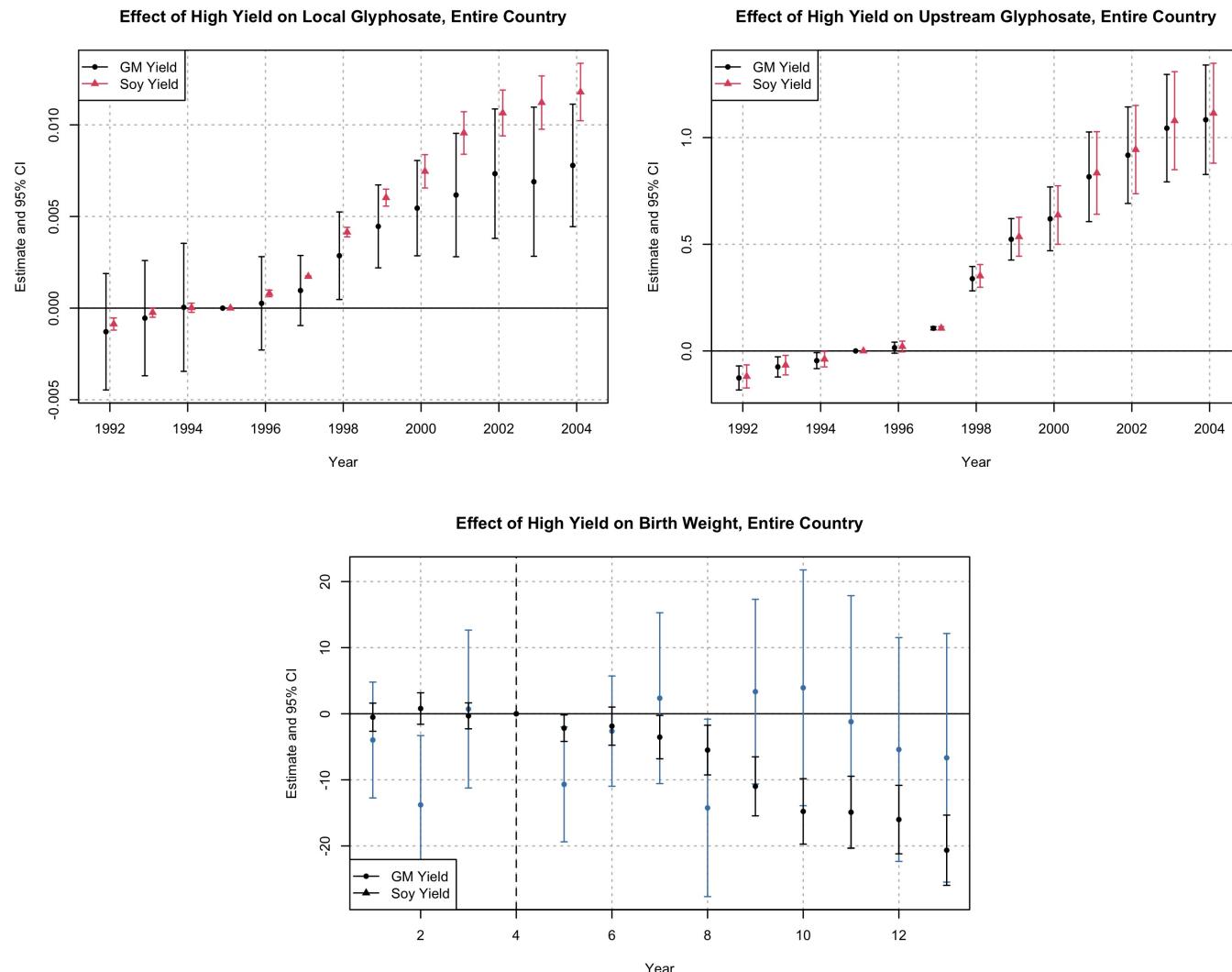
Robustness: Different splits



Robustness: Soy Attainable Yield



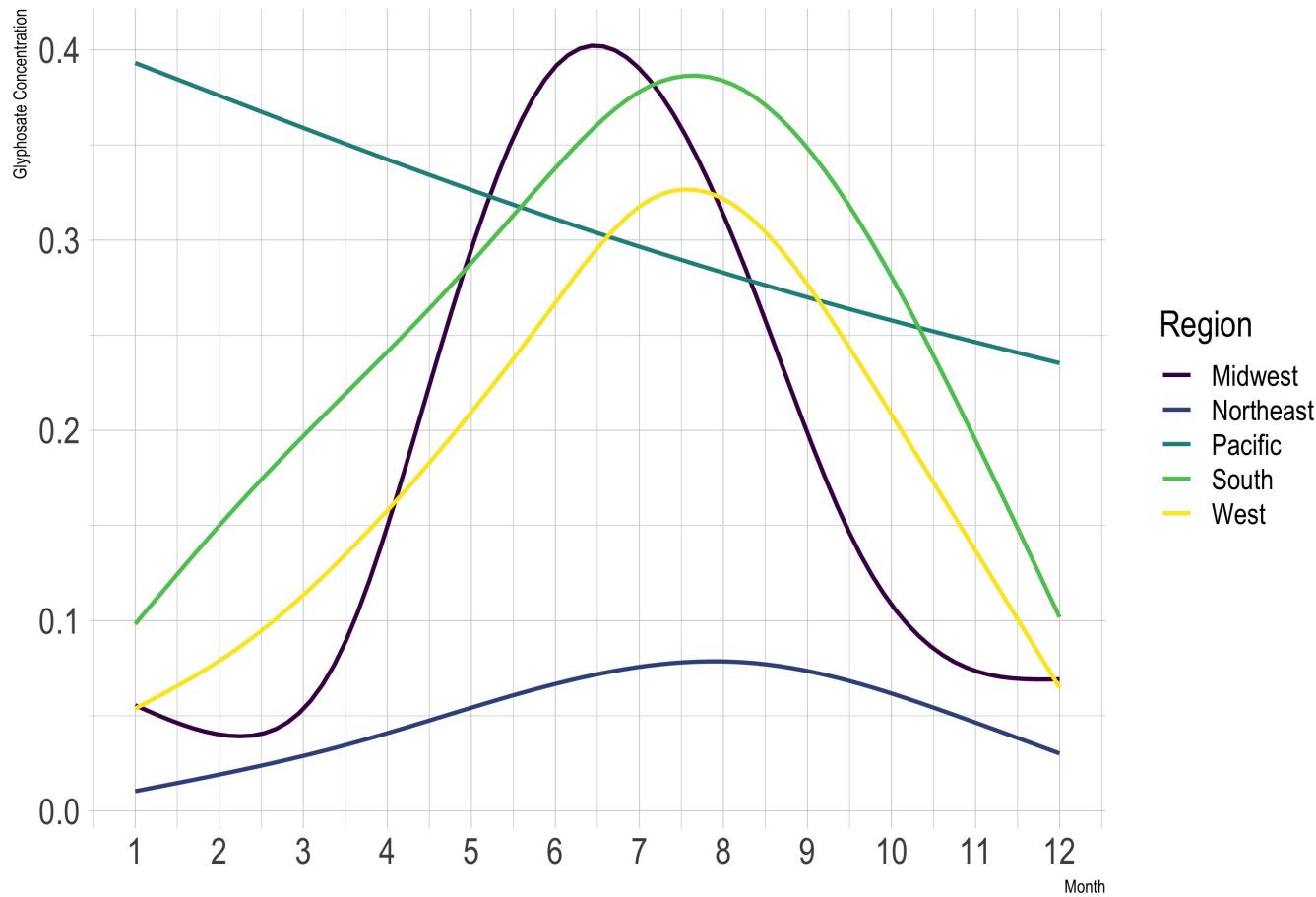
Robustness: Entire country



Upstream vs Local Effects

Glyphosate in water

Concentration of Glyphosate in Water



Upstream vs Local Effects

What is the exposure mechanism?

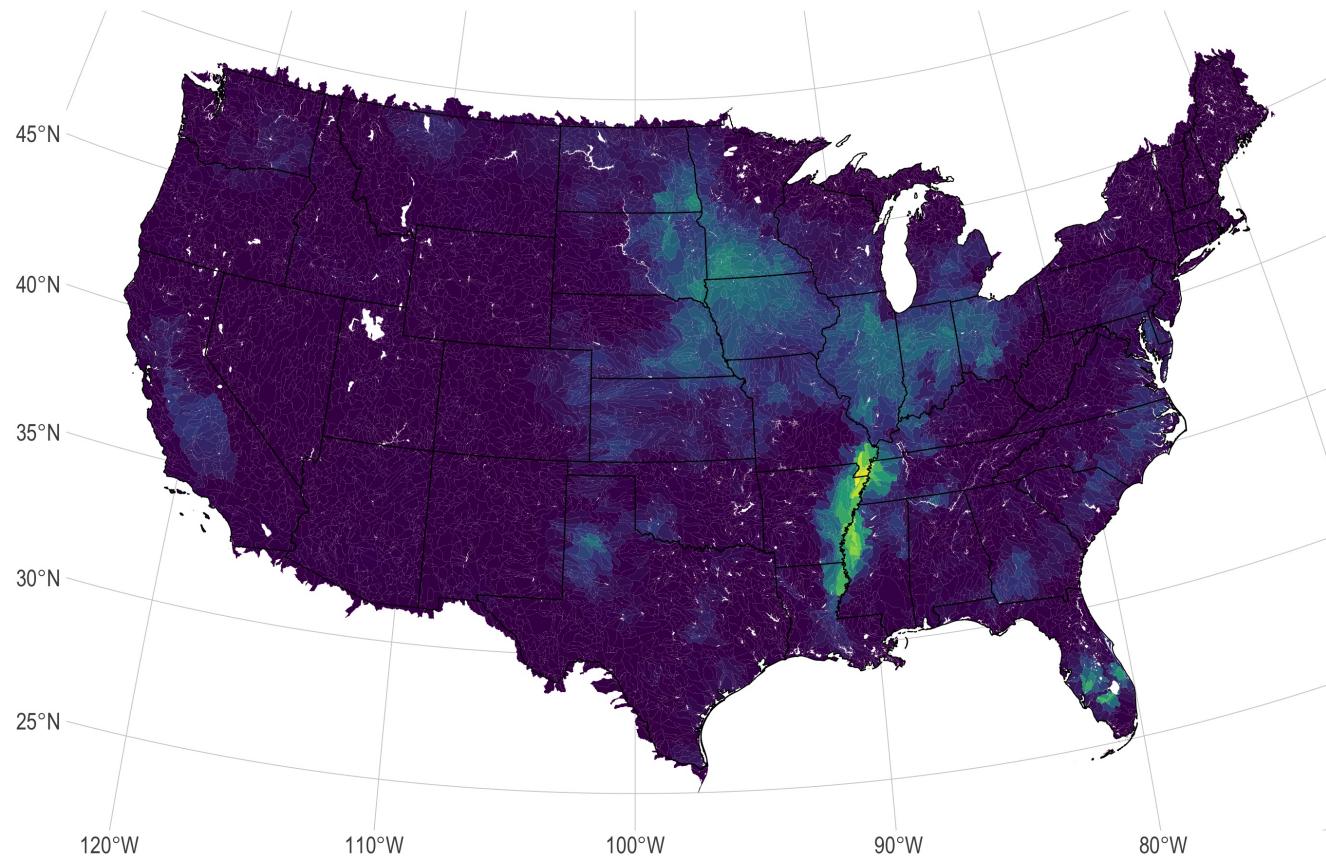
- **Direct:** Occupational exposure during/after spraying
- **Drift:** Glyphosate particles blown around by the wind
- **Water:** Glyphosate particles dissolve into water and contaminate surface or ground water

Estimate upstream glyphosate

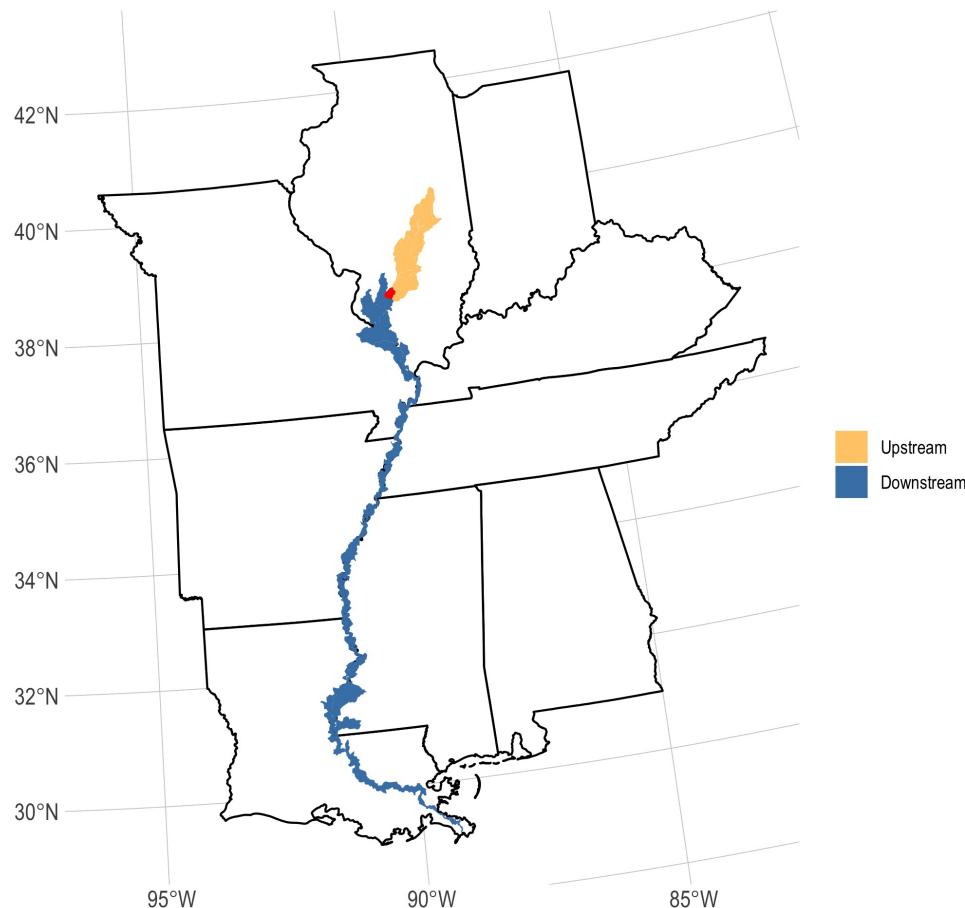
- Link counties with a spatial water model
- Aggregate upstream and downstream spraying
- Also aggregate first stage predictions from exogenous regressors

Disaggregating to watersheds

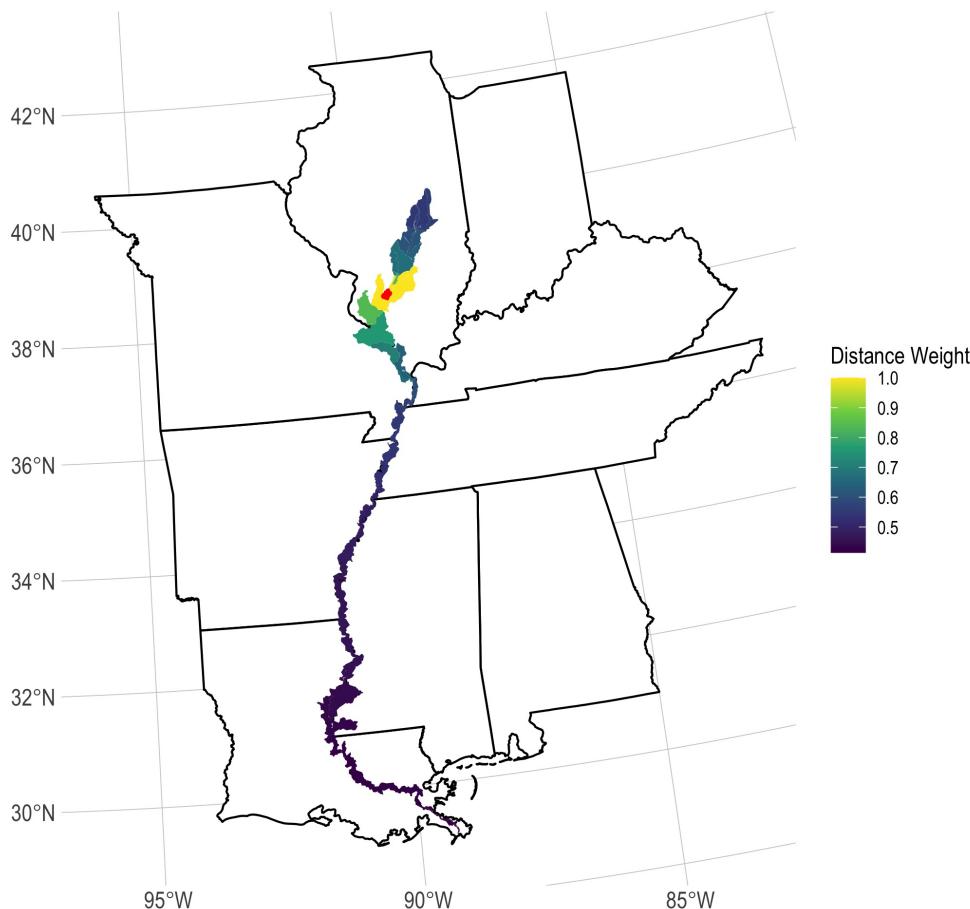
Area weighted glyphosate by watershed in 2006



Aggregating upstream glyphosate



Distance weighting



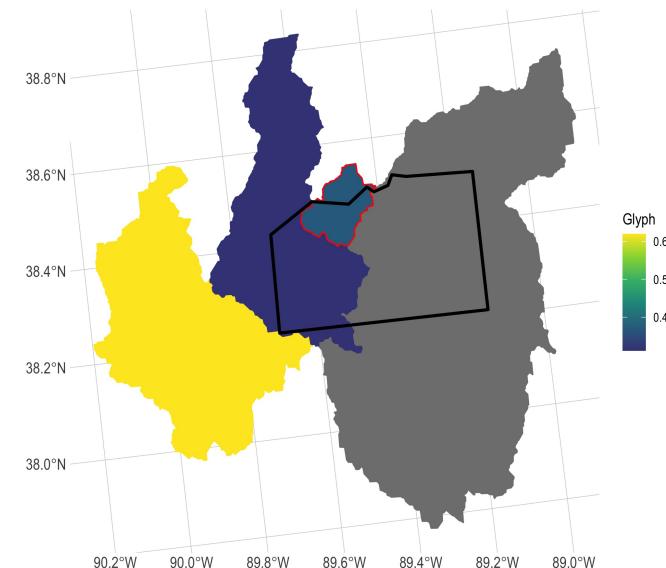
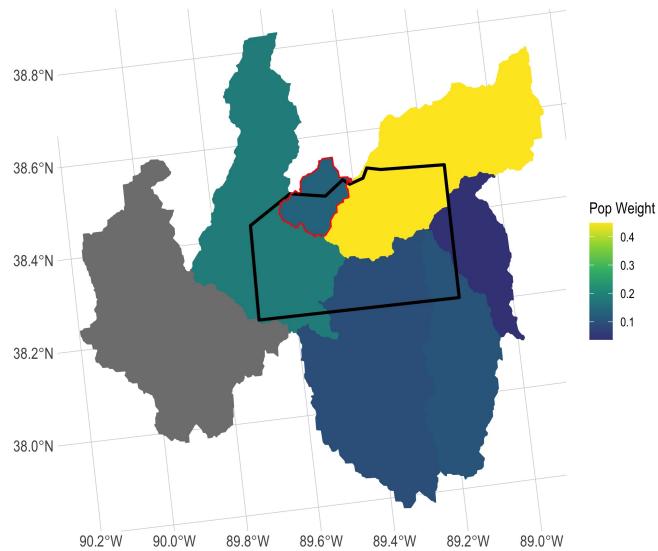
Upstream Glyphosate

Upstream Glyphosate in 2006



Adding population weights

Example: Washington County, IL



Aggregating to county level

