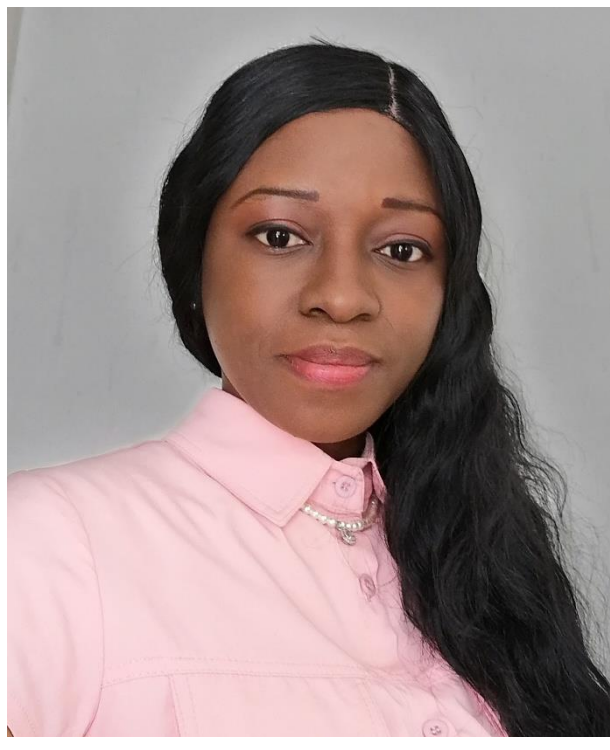


**Crop-residue burning and women's anemia outcomes:** Evidence from agricultural smoke exposure in northern India
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INTRODUCTION

- Crop-residue burning is an important seasonal pollution source.
- It contributes 10 to 30% of particulate matter (PM_{2.5}) across major Indo-Gangetic Plain (IGP) cities, exceeding 50% during peak episodes.
- Its effects on women's hemoglobin and anemia



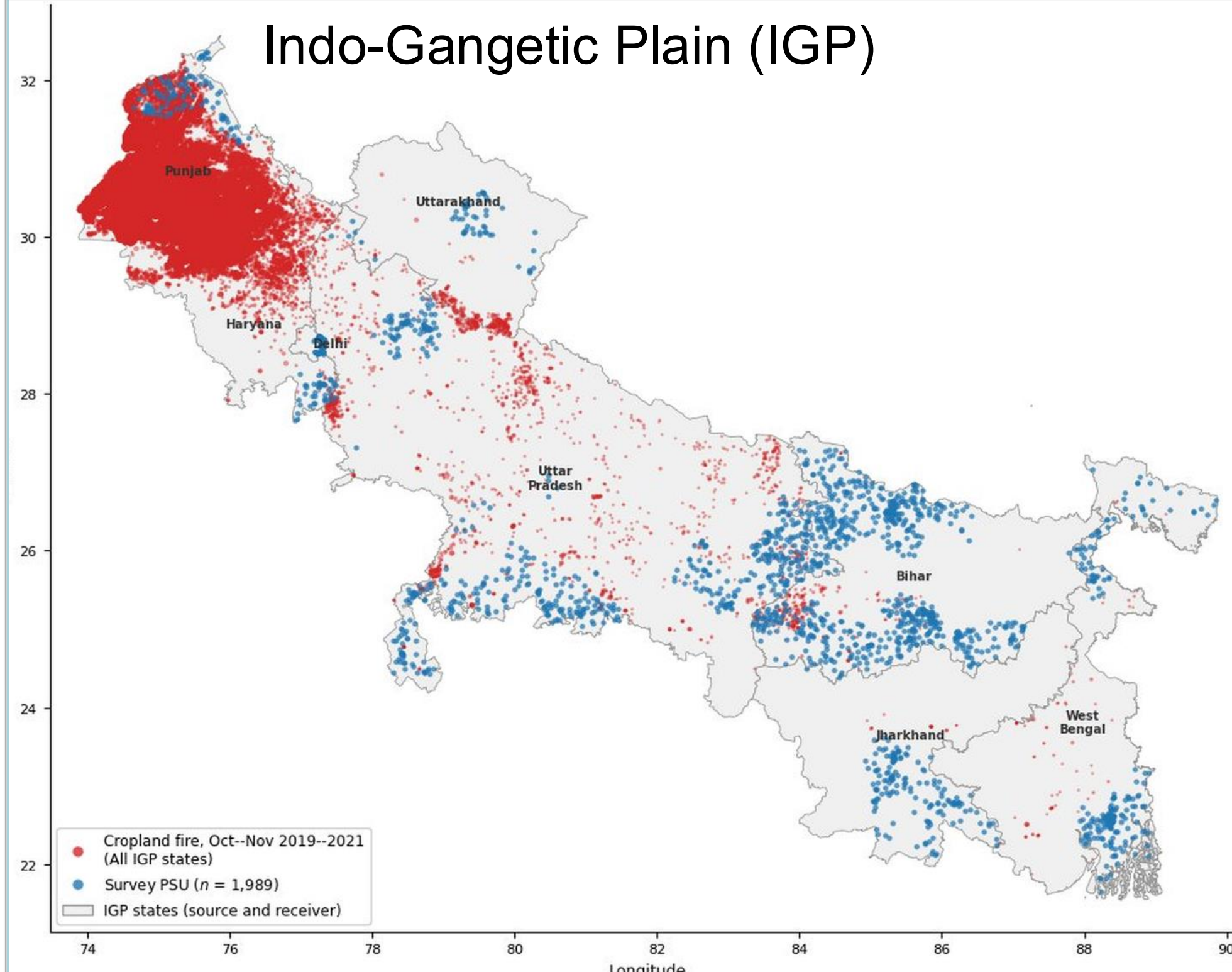
Photo: Jaskarn SH SD, Wikimedia Commons, CC BY-SA 4.0

RESEARCH QUESTION

- Does wind-transported agricultural smoke worsen women's blood health?

47,783
women68
districts55.6%
anemic11.60
mean Hb

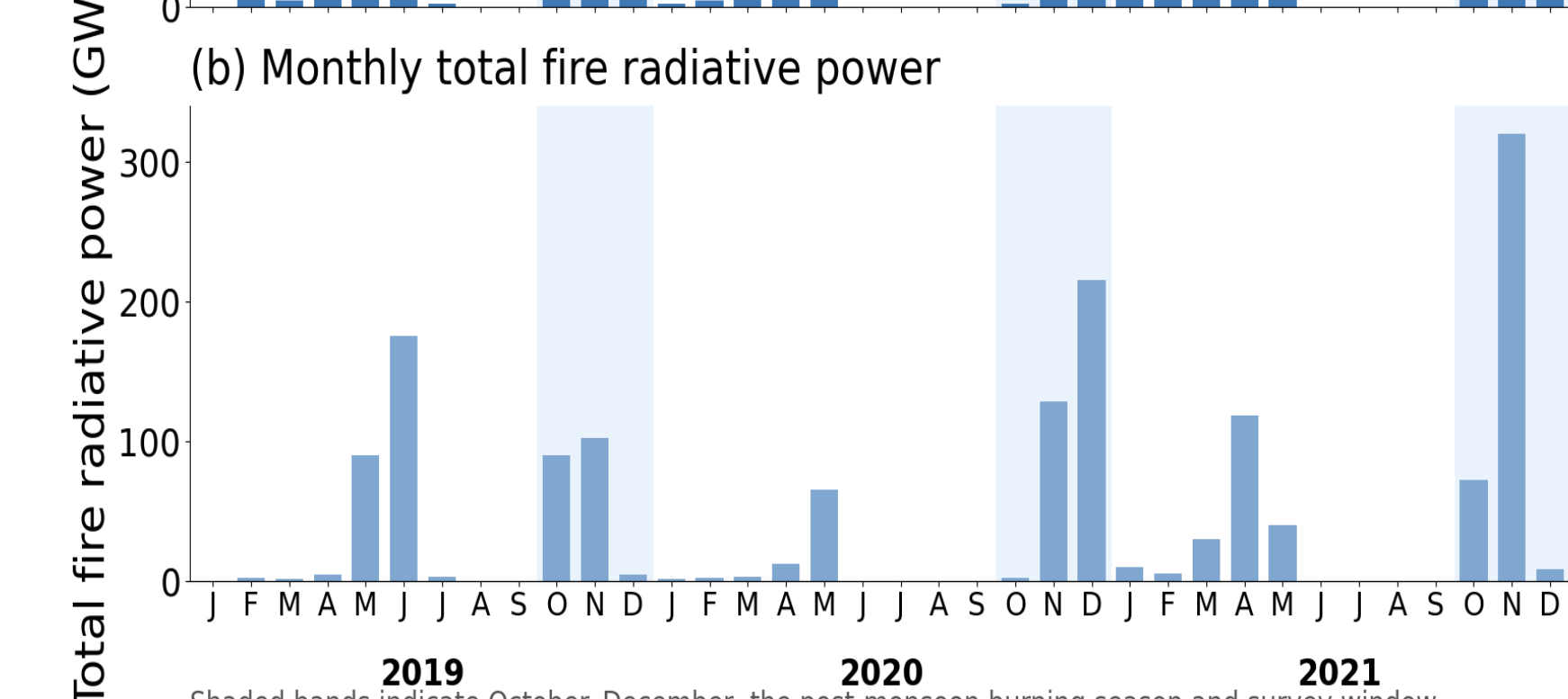
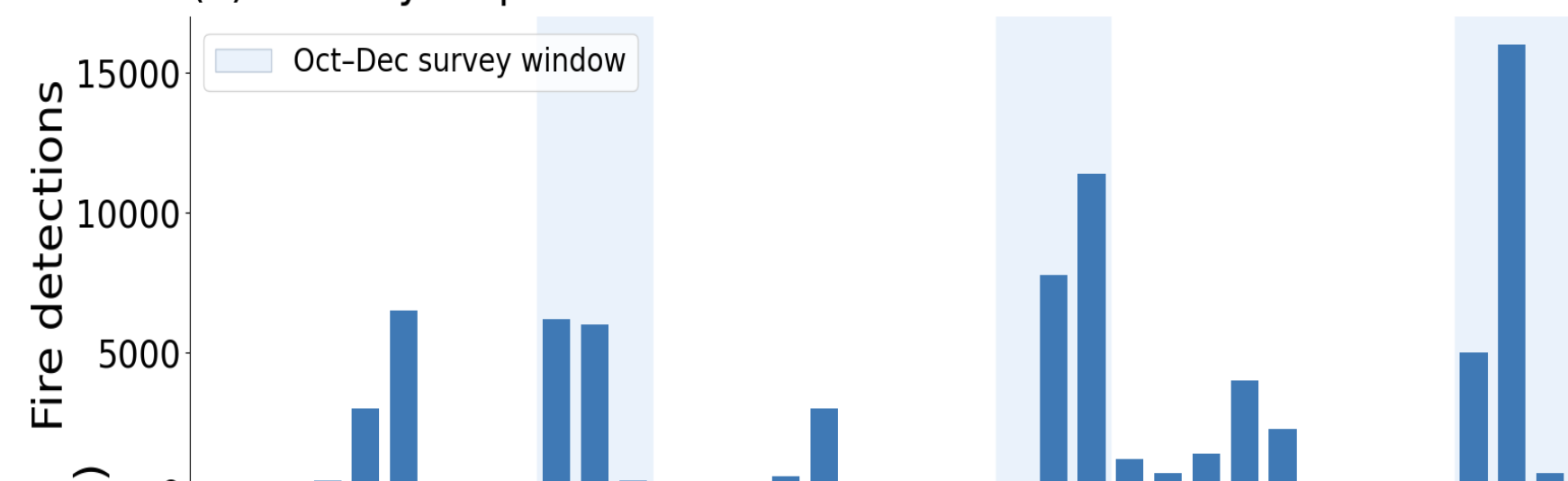
STUDY AREA AND DATA



Red = cropland fires (Oct-Nov 2019-2021) · Blue = NFHS-5 survey PSUs

NFHS-5 hemoglobin + anemia
MODIS FIRMS cropland fires
Daily wind direction + speed
PM_{2.5} + weather gridded data
Women aged 15 - 49 · interviews Oct - Dec 2019 - 2021 · 8 IGP states

WHEN DOES EXPOSURE PEAK?

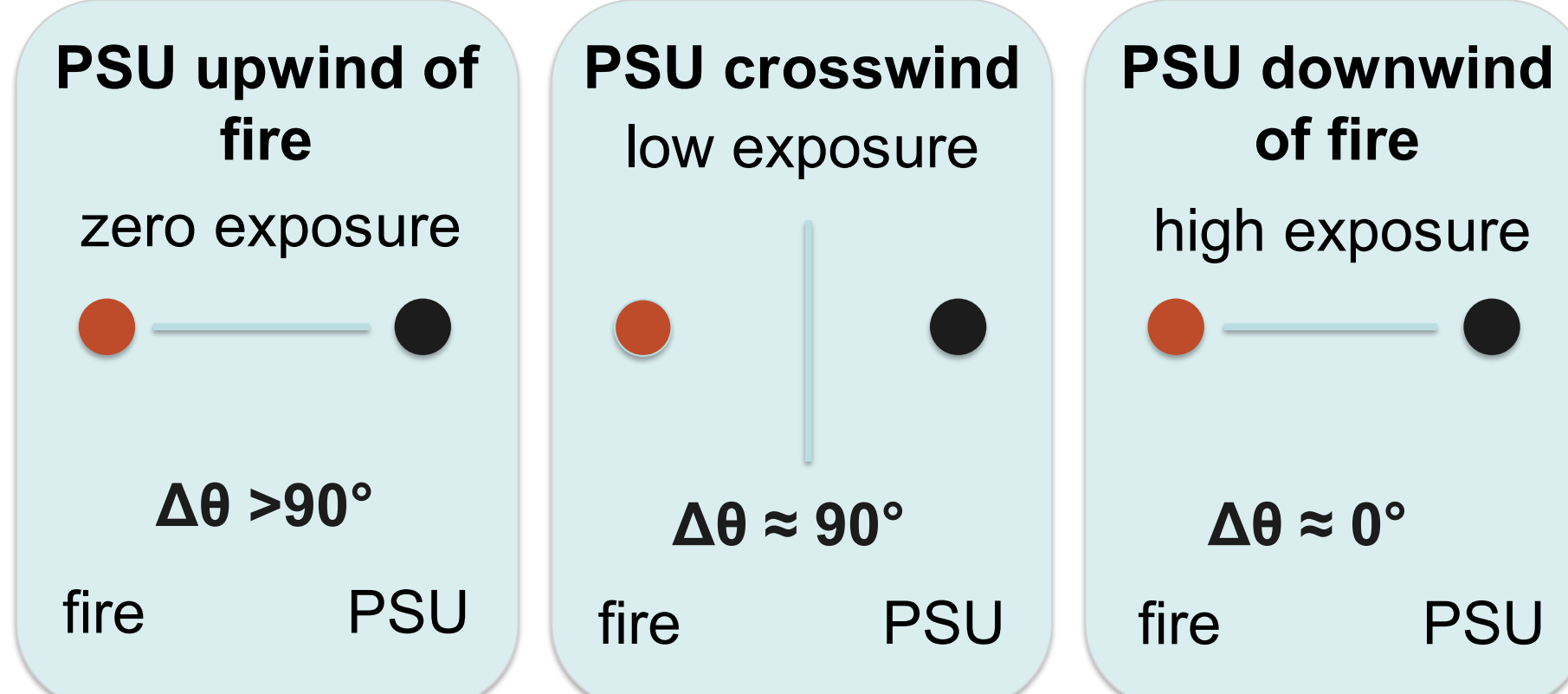
Agricultural fire activity peaks in October-November
(a) Monthly cropland fire detections

Shaded bands indicate October-December, the post-monsoon burning season and survey window.

Fire detections and fire radiative power peak sharply in October-November, matching the survey exposure window.

Descriptive figure only: it motivates the seasonal sample; it does not determine the headline effect estimates.

IDENTIFICATION

Wind direction changes smoke transport to otherwise similar primary sampling units (PSUs).

Daily wind-weighted exposure

$$w = \max[\cos(\Delta\theta), 0] / (1 + \text{distance})$$

- Nearby fires located directly upwind of a PSU receive greater weight; daily weights accumulate over the 90 days before interview.

75 km
catchment

90-day window

District-
clustered SEs

Estimating equation

$$\text{Hemoglobin / Anemia} = \beta \times \text{Wind-weighted smoke exposure} + \text{Controls} + \text{District FE} + \text{Interview year-month FE} + \text{Error term}$$

- Key assumption: conditional on fixed effects and weather, daily wind direction is plausibly exogenous.

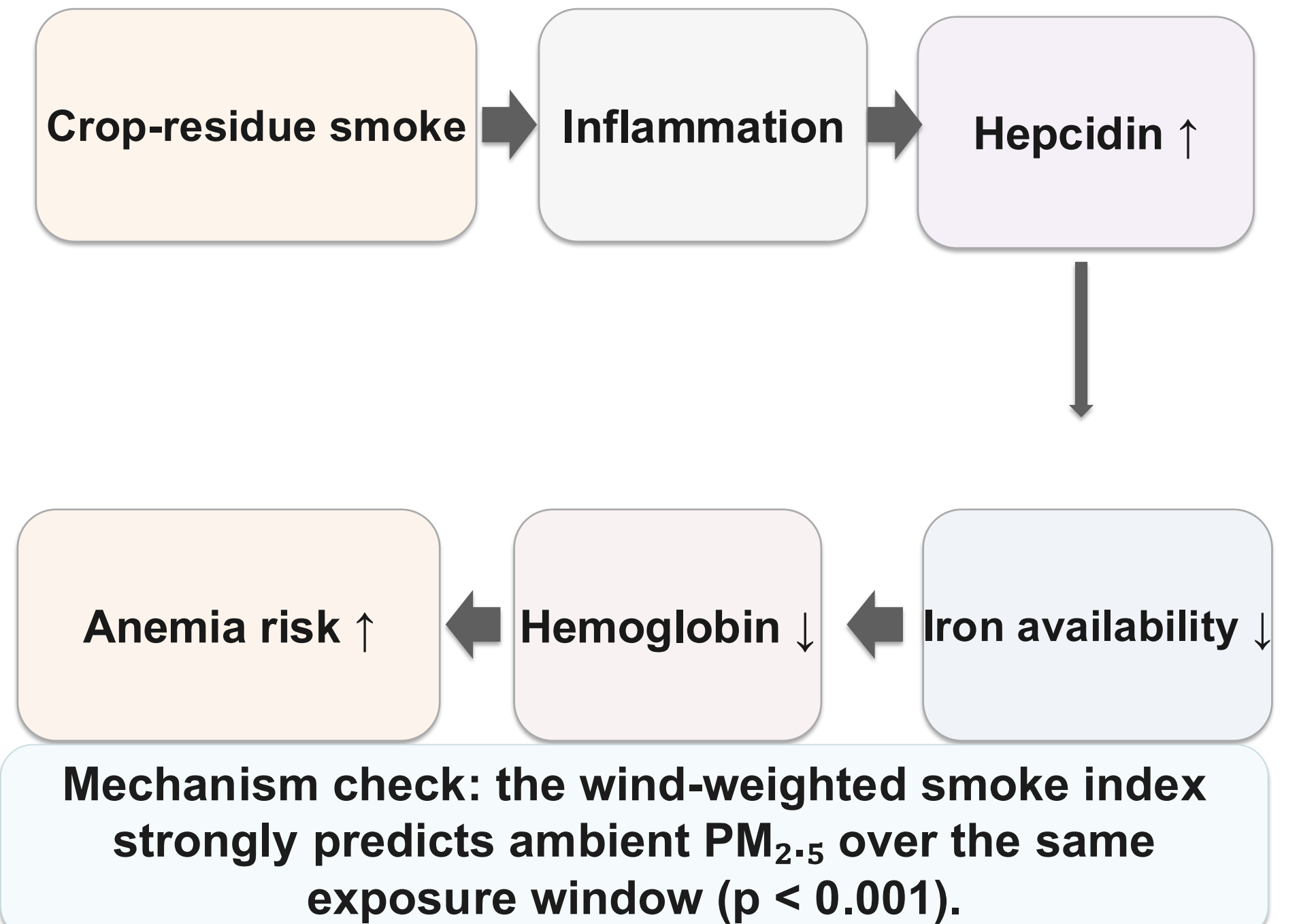
RESULTS

	Altitude-adjusted hemoglobin (g/dL)	Anemia
Wind-weighted smoke exposure	-0.0104*** (0.00195)	0.00269*** (0.00056)
Effect of 1-SD increase	-0.028 g/dL	+0.72 pp
Observations	47,783	47,783
Districts	68	68
District FE	Yes	Yes
Year-month FE	Yes	Yes
Controls	Yes	Yes

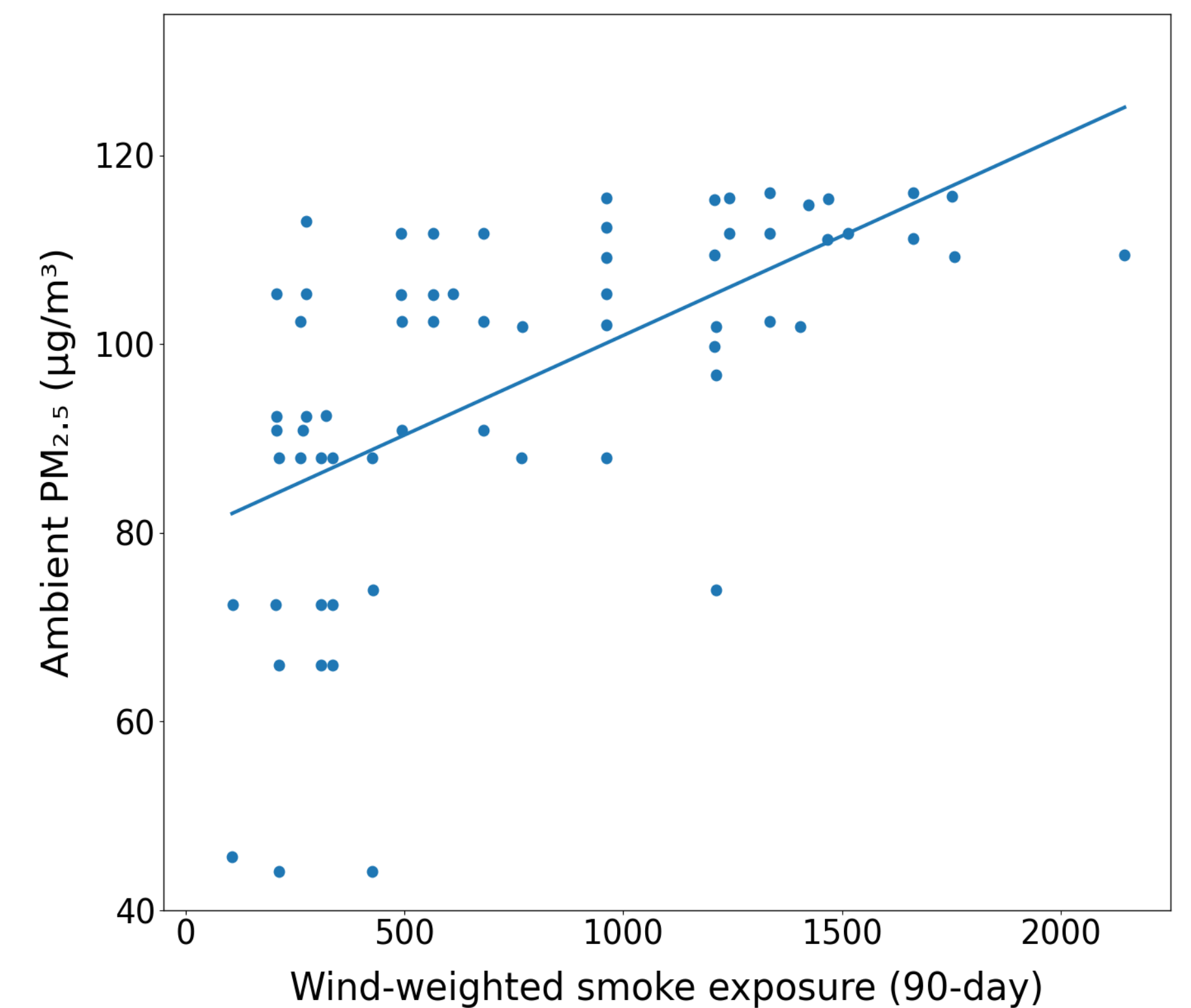
INTERPRETATION

- Higher wind-weighted smoke exposure is associated with lower hemoglobin and higher anemia risk.
- A 1-SD increase in 90-day smoke exposure lowers hemoglobin by 0.028 g/dL.
- The same increase raises the probability of anemia by 0.72 percentage points.
- Both effects are highly statistically significant ($p < 0.001$).

MECHANISM



Thiagarajan et al. (2021); Xie et al. (2022)

Wind-weighted smoke exposure predicts ambient PM_{2.5}

ROBUSTNESS & FALSIFICATION

Does the smoke-transport story survive alternative tests?**60-day window**
Same sign; larger effect**Future exposure**
Placebo is null**Functional form**
log(1+exposure) check**Alternative radius**
100 km remains supportive

CONTRIBUTION

- Causal evidence on women's hemoglobin and anemia from a source-specific pollution shock.
- Connects agricultural residue management to a downstream public-health externality.
- Shows that health costs extend well beyond the districts where burning occurs.

POLICY MESSAGE

Reducing crop-residue burning could yield health benefits far beyond Punjab and Haryana.

Policies that reduce agricultural burning can lower pollution exposure in downwind populations.