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

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Abstract

Post-monsoon crop-residue burning is a primary driver of seasonal particulate pollution across the Indo-Gangetic Plain in India, yet its causal health consequences for rural women remain poorly documented. While existing literature links ambient PM_{2.5} to anemia and respiratory outcomes, causal evidence from rural settings and agricultural pollution sources is scarce. This study examines whether wind-transported agricultural smoke worsens hemoglobin status and increases anemia risk among rural women, using individual health data from the Indian National Family Health Survey (NFHS-5) combined with satellite-derived fire activity, wind fields, and gridded pollution data.

The estimation sample comprises 47,783 women interviewed during the October–December burning season across eight Indo-Gangetic Plain states and 68 districts. Identification exploits plausibly exogenous day-to-day variation in wind direction and speed to construct wind-weighted smoke exposure indices over 60-day and 90-day trailing windows. Models include district and interview year-month fixed effects, absorbing confounding seasonal and geographic variation alongside controls for weather and household characteristics. PM_{2.5} is examined as a mechanism check rather than the primary estimand, since agricultural smoke carries a complex pollutant mixture and instrumenting for PM_{2.5} alone would require an exclusion restriction that is difficult to defend in this setting.

In the main 90-day reduced-form specification, a one-standard-deviation increase in wind-weighted smoke exposure reduces altitude-adjusted hemoglobin by 0.028 g/dL ($p < 0.001$) and raises anemia probability by 0.72 percentage points ($p < 0.001$). The smoke index strongly predicts ambient PM_{2.5} concentrations over the same window, supporting a pollution-transport pathway. Results are robust to alternative window lengths, exposure radii of 75, 100, and 150 kilometres, functional form, and a range of placebo and falsification tests including future-exposure placebos, randomisation-based falsification, and predetermined covariate balance checks.

These findings provide causally identified evidence that crop-residue burning imposes measurable health costs on rural women across the Indo-Gangetic Plain, with direct implications for agricultural residue management, environmental regulation, and rural public health policy across India.

Keywords: Agricultural smoke, anemia, causal identification, crop-residue burning, hemoglobin, India, Indo-Gangetic Plain, pm_{2.5}, rural women, wind-weighted exposure

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