Rainfall shocks, soil health and child health outcomes in rural India

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Motivation

- **Research question.** What is the heterogeneous impact of rainfall shocks by variation in the soil health for child health outcomes in rural India?
- Regions with a higher agricultural growth have a lower incidence of child stunting (Webb and Block, 2012).
- India shows the poorest performance in the global south for child health outcomes (FAO, UNICEF, and WHO, 2018).

Conceptual Framework

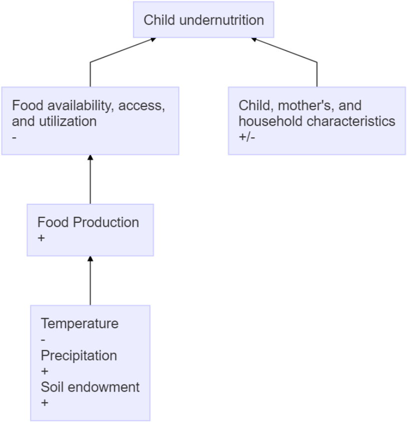
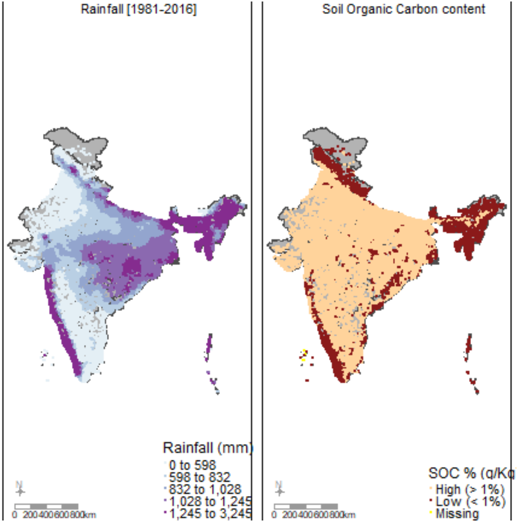


Figure: 1. A simple conceptual link between temperature, precipitation, soil health and child under nutrition.

Map of the study area



Source: DHS, CHIRPS and OpenLandMap data.

Data

- Demographic and Health Survey (DHS Round-IV, 2015-16) for India.
- Rainfall [1981-2016] data is constructed from the Climate Hazards Group Infrared Precipitation (CHIRPS) at $0.05°$ resolution.
- Growing degree days [2010-2015] is constructed from the National Centre for Medium Range Weather Forecasting (NCMRWF) at $0.1°$ resolution.
- Soil organic carbon content data were collected from the OpenLandMap (Hengl, 2018a, 2018b; Hengl and Wheeler, 2018) at $250-$ m resolution.

Construct climate variables

- I calculate total rainfall for the growing season for each year of the child's life and average those values over the life of each child.

- I calculate the depth-weighted soil organic carbon content at 0-60 cm using the trapezoidal rule. A1

- I calculate the growing degree days (lower and upper bound using thresholds 29°C and 34°C respectively) applying a sine curve temperature approximation from daily maximum and minimum temperature. A2

Crop yields and rainfall deciles

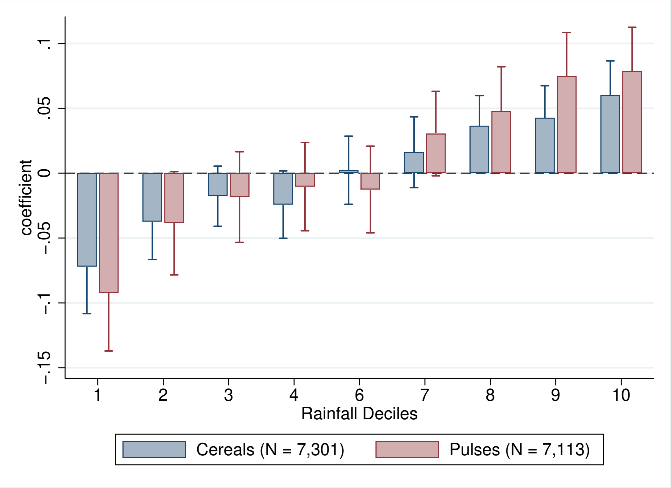
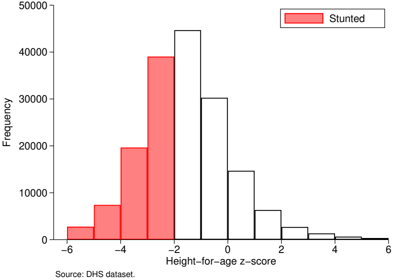
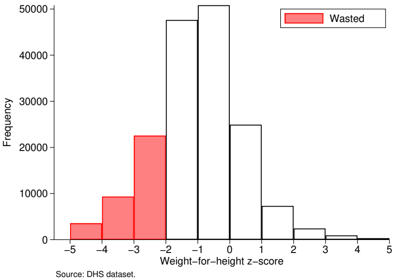


Figure: 1. Coefficient for rainfall deciles and 95% CI in India. The dependent variable is the natural logarithm of annual crop yield (kg per hectare) from 2001 to 2015. The specification include district and year fixed effects. The 5th decile is selected as reference.

Distribution of height-for-age (HAZ) and weight-for-height (WHZ) z-scores of children aged 0-5 years.



(a) Stunted (HAZ< -2)



(b) Wasted (WHZ< -2)

Data

Table: 2. Summary statistics (N = 169,904).

	Mean	Std. Dev.
Child health outcomes, yes=1		
Stunted (HAZ< -2)	0.405	0.491
Wasted (WHZ< -2)	0.209	0.406
Rainfall variables below 20th percentile, yes=1		
Rainfall shock - in-utero	0.110	0.313
Rainfall shock - year of birth	0.110	0.312
Rainfall shock - 1st year	0.126	0.332
Rainfall shock - 2nd year	0.118	0.323
Rainfall shock - 3rd year	0.097	0.296
Rainfall shock - 4th year	0.063	0.242
Fraction of shocks[a]	0.134	0.182

a: $\frac{\text{[exposure to shocks in-utero through 4]}}{\text{in-utero + child's age}}$

Source: DHS and CHIRPS data.

Base specification:

$$h_i = \beta_0 + \beta_1 shock_j + \beta_2 rain_j + \beta_3 gdd_j + \beta_4 (shock_j * highsoc_j) + \xi \mathbf{X}_i + f(a)_i + \gamma_j + \delta_d + \rho_{my} + \epsilon_i \quad (1)$$

Specification 2:

$$h_{iy} = \beta_0 + \beta \Theta_{jy} + \alpha (\Theta_{jy} * highsoc_j) + \xi \mathbf{X}_i + f(a)_i + \gamma_j + \delta_d + \rho_{my} + \epsilon_{iy}, \quad (2)$$

$$y = in - utero, 0, 1, 2, 3, 4.$$

Results

Table: 1 Effect of rainfall shocks on child health outcomes.

	HAZ	WAZ	WHZ
Fraction of shocks	0.019	-0.124***	-0.234***
	(0.053)	(0.036)	(0.048)
Rainfall (mm)	0.00007	0.00001	-0.00002
	(0.00006)	(0.00004)	(0.00005)
GDD (days)	-0.004*	0.002	0.005**
	(0.003)	(0.002)	(0.002)
Frac shocks x High SOC (> 1%)	0.076	0.145*	0.172*
	(0.121)	(0.083)	(0.104)
Observations	169,512	169,512	169,512
Adjusted R^2	0.202	0.221	0.147

Robust standard errors clustered at the DHS cluster level in parentheses.
Include controls for child, mother, and household characteristics;
DHS cluster, district and month-birth year FEs.
* $p < 0.1$;** $p < 0.05$;*** $p < 0.01$.

Child health outcomes and timing of exposure to rainfall shocks

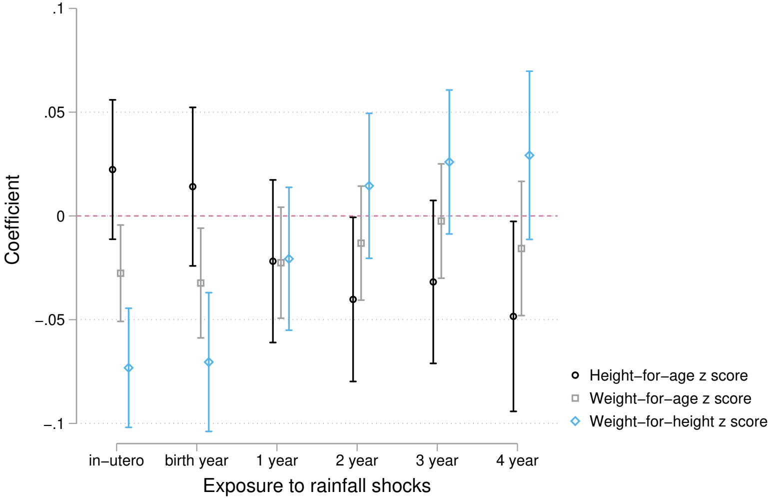


Figure: 3. Coefficient of child health outcomes on the timing of exposure to rainfall shocks and 95% CI.

Interaction effects between timing of rainfall shocks and high SOC (> 1%).

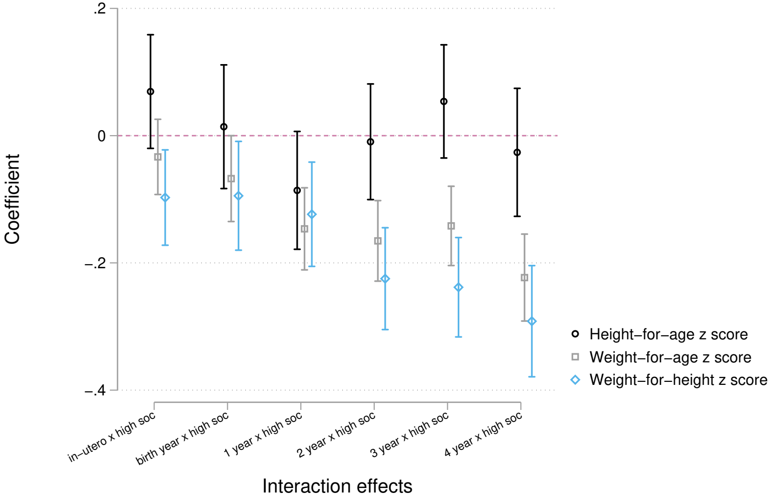


Figure: 4. Coefficient of child health outcomes on the interaction between the timing of exposure to rainfall shocks and high soil organic carbon content, and 95% CI.

Results

Table: 2 Heterogeneous effects of rainfall shocks on child weight-for-height z-scores by region.

	All	North central	South
Fraction of shocks	-0.234***	-0.123*	0.113
	(0.048)	(0.064)	(0.234)
Rainfall (mm)	-0.00002	0.0001	-0.00004
	(0.00005)	(0.0001)	(0.00003)
GDD (days)	0.005**	-0.006	0.003
	(0.002)	(0.005)	(0.010)
Frac shocks x High SOC ($> 1\%$)	0.172*	0.548	-0.411
	(0.104)	(0.441)	(0.392)
Observations	169,512	56,562	11,604
Adjusted R^2	0.147	0.112	0.111

Robust standard errors clustered at the DHS cluster level in parentheses.
Include controls for child, mother, and household characteristics;
DHS cluster, district and month-birth year FEs.
* $p < 0.1$;** $p < 0.05$;*** $p < 0.01$.

Results

Table: 3 Heterogeneous effects of rainfall shocks on child weight-for-height z-scores by wealth.

	All	Poor	Non-poor
Fraction of shocks	-0.234***	-0.263***	-0.130*
	(0.048)	(0.066)	(0.071)
Rainfall (mm)	-0.00002	0.00005	-0.00002
	(0.00005)	(0.00008)	(0.00007)
GDD (days)	0.005**	0.009**	0.004
	(0.002)	(0.004)	(0.003)
Frac shocks x High SOC ($> 1\%$)	0.172*	0.195	0.069
	(0.104)	(0.177)	(0.134)
Observations	169,512	74,386	91,332
Adjusted R^2	0.147	0.135	0.150

Robust standard errors clustered at the DHS cluster level in parentheses.
Include controls for child, mother, and household characteristics;
DHS cluster, district and month-birth year FEs.
* $p < 0.1$;** $p < 0.05$;*** $p < 0.01$.

Results

Table: 4 Heterogeneous effects of rainfall shocks on child weight-for-height z-scores by gender.

	All	Female	Male
Fraction of shocks	-0.234***	-0.269***	-0.197***
	(0.048)	(0.068)	(0.070)
Rainfall (mm)	-0.00002	0.00002	-0.00007
	(0.00005)	(0.00008)	(0.00007)
GDD (days)	0.005**	0.005	0.005
	(0.002)	(0.003)	(0.003)
Frac shocks x High SOC ($> 1\%$)	0.172*	0.211	0.030
	(0.104)	(0.148)	(0.158)
Observations	169,512	80,046	85,734
Adjusted R^2	0.147	0.141	0.146

Robust standard errors clustered at the DHS cluster level in parentheses.
Include controls for child, mother, and household characteristics;
DHS cluster, district and month-birth year FEs.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Results

Table: Heterogeneous effect of rainfall shocks on female child with at least one male sibling.

	All	Female	Male sibling
Fraction of shocks	-0.235***	-0.269***	-0.282***
	(0.048)	(0.069)	(0.109)
Rainfall (mm)	-0.00002	0.00002	-0.0002*
	(0.00005)	(0.00008)	(0.0001)
GDD (days)	0.005**	0.005	0.015**
	(0.002)	(0.003)	(0.006)
Frac shocks x High SOC ($> 1\%$)	0.172*	0.209	0.154
	(0.104)	(0.148)	(0.245)
Observations	169,512	80,046	36,901
Adjusted R^2	0.147	0.141	0.138

Robust standard errors clustered at the DHS cluster level in parentheses.
Include controls for child, mother, and household characteristics;
DHS cluster, district and month-birth year FEs.
* $p < 0.1$;** $p < 0.05$;*** $p < 0.01$.

Results

Table: 6 Effects of rainfall shocks on likelihood of child stunting and wasting.

	Rainfall $< P_{20}$		SPEI ≤ -1	
	Stunted	Wasted	Stunted	Wasted
Fraction of shocks	0.87**	1.59***		
	(0.06)	(0.12)		
Frac shocks x High SOC ($> 1\%$)	1.01	0.77		
	(0.18)	(0.14)		
Fraction of shocks			0.87	1.14
			(0.09)	(0.14)
Frac shocks x High SOC ($> 1\%$)			1.59	0.31**
			(0.65)	(0.17)
Observations	158,288	136,865	158,288	136,865

Exponentiated coefficients;
Robust standard errors clustered at the DHS cluster level in parentheses.
Include controls for child, mother, and household characteristics
** $p < 0.05$; *** $p < 0.01$.

- All weather variables are extracted at the buffer area of 10 km around DHS cluster. Robustness check using different set of buffer area (not performed).
- Growing degree days can also be understood as a proxy of heat stress on rural households.
- Alternate measure of weather variable using Standardized Precipitation Evatransporation Index (SPEI) leads to a more conservative coefficient estimates on shocks.

Appendix A1

The depth-weighted soil organic carbon content at 0-60 cm interval using the trapezoidal rule:

$$Soil_{0-60cm} = \frac{[(Soil_{0cm} + Soil_{10cm}) * 10 * 0.5]}{60} + \frac{[(Soil_{10cm} + Soil_{30cm}) * 20 * 0.5]}{60} + \frac{[(Soil_{30cm} + Soil_{60cm}) * 30 * 0.5]}{60}$$

return

Appendix A2

Following Snyder (1985), the growing degree days is calculated as: $GDD = \sum_s^S [D(T_L) - D(T_U)]$, where s represents the number of days in a growing season.

$$D(T_L) = \begin{cases} 1, & \text{if } T_{min} > 29°C \\ (\pi - 2\theta^{29°C})/2\pi, & \text{if } T_{min} \leq 29°C \end{cases}$$

$$D(T_U) = \begin{cases} 1, & \text{if } T_{min} > 34°C \\ (\pi - 2\theta^{34°C})/2\pi, & \text{if } T_{min} \leq 34°C \end{cases}$$

$$M = \frac{T_{max} + T_{min}}{2}; W = \frac{T_{max} - T_{min}}{2}$$

$$\theta^{29°C} = arcsin[(29°C - M)/W]; \theta^{34°C} = arcsin[(34°C - M)/W]$$

return