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; Pingali, 2019).
- India shows the poorest performance in the global south for child health outcomes (FAO, UNICEF, and WHO, 2018).

Conceptual Framework

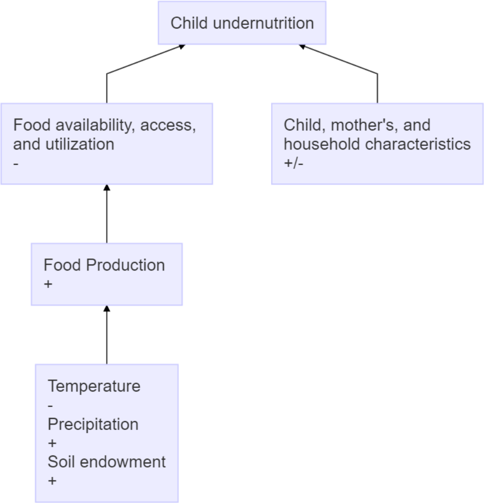
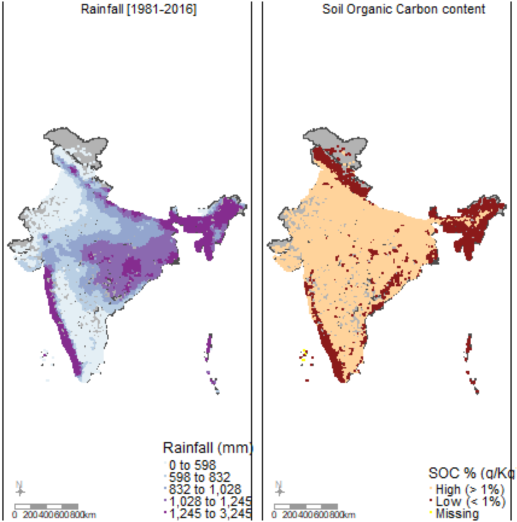


Figure: 1. A simple conceptual link between temperature, precipitation, soil health and child undernutrition.

Contributions

- A better soil endowment reduces the effect of rainfall shocks on child health outcomes.
- Growing degree days reduces the effect of rainfall shocks on child health outcomes.
- Following heterogeneous effects of rainfall shocks on child health outcomes:
  - Higher vs lower incidence regions
  - Poor vs non-poor households
  - Female vs male siblings effect

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 fraction of shocks as:

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

- 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.

- Lower and upper bound daily temperature thresholds of 29°C and 34°C, respectively are used to calculate the growing degree days. Appendix A2

Crop yields and rainfall deciles

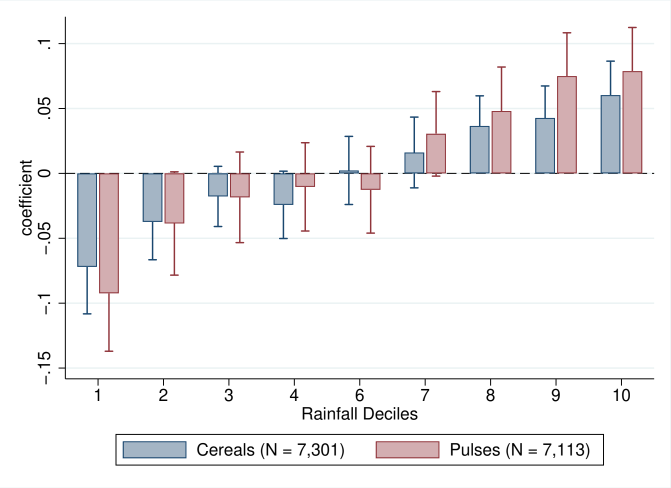
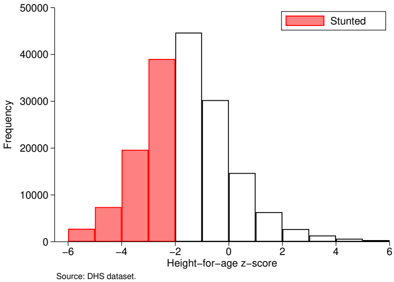
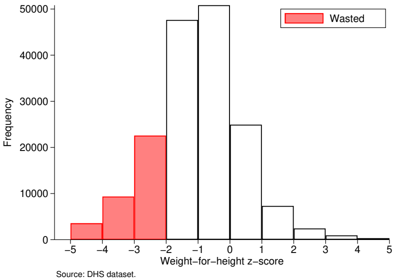


Figure: 1. Coefficient for rainfall deciles and 95% CI in India. The dependent variable is the natural logarithm of annual crop yield (kg per hectare) from 2001 to 2015. The specification include district and year fixed effects. The 5th decile is selected as reference.

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)

Summary statistics

	Obs.	Mean	Std. Dev.
Child health outcomes, yes=1			
Stunted (HAZ< -2)	169,904	0.405	0.491
Wasted (WHZ< -2)	169,904	0.209	0.406
Rainfall below 20th percentile, yes=1			
Rainfall shock - in-utero	169,904	0.110	0.313
Rainfall shock - birth year	169,904	0.110	0.312
Rainfall shock - 1st year	137,807	0.125	0.331
Rainfall shock - 2nd year	103,642	0.148	0.355
Rainfall shock - 3rd year	69,621	0.168	0.374
Rainfall shock - 4th year	33,951	0.167	0.373
Fraction of shocks	169,904	0.134	0.182

Source: DHS and CHIRPS data.

Base specification:

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

Specification 2:

$$h_{iy} = \beta_0 + \beta \sum_y \Theta_{jy} + \gamma \sum_y (\Theta_{jy} * highsoc_j) + \xi \mathbf{X}_i + \lambda_j + \delta_d + \phi_{my} + \epsilon_{iy}, \quad y = \{in-utero, 0, 1, 2, 3, 4\}. \quad (2)$$

Effects 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

Dependent variable is the child's weight-for-height z score.
Robust standard errors clustered at the DHS cluster level in parentheses.
Include controls for child, sibling, 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.

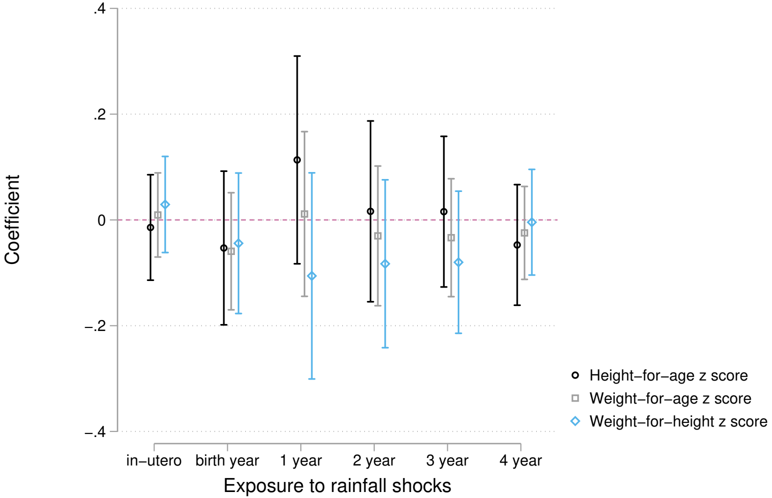


Figure: 3. Coefficient of child health outcomes on the timing of exposure to rainfall shocks and 95% CI (N=28,072).

Heterogeneity by higher and lower incidence regions

	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

Dependent variable is the child's weight-for-height z score.
Robust standard errors clustered at the DHS cluster level in parentheses.
Include controls for child, sibling, mother, and household characteristics;
DHS cluster, district and month-birth year FEs.
* $p < 0.1$;** $p < 0.05$;*** $p < 0.01$.

Heterogeneity by poor and non-poor households

	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

Dependent variable is the child's weight-for-height z score.
Robust standard errors clustered at the DHS cluster level in parentheses.
Include controls for child, sibling, mother, and household characteristics; DHS cluster, district and month-birth year FEs.
* $p < 0.1$;** $p < 0.05$;*** $p < 0.01$.

Heterogeneity by female and male child

	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

Dependent variable is the child's weight-for-height z score.
Robust standard errors clustered at the DHS cluster level in parentheses.
Include controls for child, sibling, mother, and household characteristics; DHS cluster, district and month-birth year FEs.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Heterogeneity by female child with at least one female versus male sibling

	All	Female sib	Male sib
Fraction of shocks	-0.235***	-0.434***	-0.282***
	(0.048)	(0.101)	(0.109)
Rainfall (mm)	-0.00002	0.0002	-0.0002*
	(0.00005)	(0.0001)	(0.0001)
GDD (days)	0.005**	0.005	0.015**
	(0.002)	(0.005)	(0.006)
Frac shocks x High SOC ($> 1\%$)	0.172*	0.211	0.154
	(0.104)	(0.231)	(0.245)
Observations	169,512	38,130	36,901
Adjusted R^2	0.147	0.156	0.138

Dependent variable is the child's weight-for-height z score.
Robust standard errors clustered at the DHS cluster level in parentheses.
Include controls for child, sibling, mother, and household characteristics;
DHS cluster, district and month-birth year FEs.
* $p < 0.1$;** $p < 0.05$;*** $p < 0.01$.

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, sibling, mother, and household characteristics
** $p < 0.05$; *** $p < 0.01$.

- Findings:
    - One standard deviation above mean exposure to rainfall shock results in a 0.02 to 0.05 more negative weight-for-height z score.
    - A move from low to high soil endowment provides a resilient of 0.172 points in response to rainfall shocks.
    - An additional day of growing degree days results in a 0.005 more positive weight-for-height z score.
- Robustness check:
    - Results hold when a different buffer area that is 20 km is used.

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.

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

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

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

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

return