The Green Revolution and Rural Inequality: India

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The Green Revolution: Global

- Paired introduction of high-yielding varieties (primarily rice, wheat) with increased irrigation and modern inputs
  - Early period 1961-1980, later period 1980-2000.
- Higher yields, intensification *and* land expansion, lower grain prices, decreased mortality and fertility rates, increased life expectancy, smaller populations, increased per capita GDP, increased non-ag labor productivity after a decade (Evenson & Gollin 2003; Gollin, Hansen, Windgender 2018; McArthur & McCord 2017)
- Surprising lack of focus on poverty, hunger, and inequality.
  - GR meant to provide "a lasting solution" to the "perpetual problems of rural poverty and hunger," and to kickstart rural economies so as to "improve the quality of life at the grassroots in an appreciable measure" (Dhanagare 1987)

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Distributional Concerns

In fact, economists from the GR era in India* were highly concerned with distributional consequences, writing:

- Smallest farmers failing to adopt HYVs, taking out more credit to do so, or profiting less from them
- Controversy over the impact of HYVs on ag wages
- Landlords converting tenants/sharecroppers into laborers, possibly eroding land reform
- Increased skewness in land, farming assets, rural welfare
  - Dhanagare (1987): "[A]ll available statistics indicate greater and greater immiseration and pauperisation as the green revolution technology package has spread in... India."

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We Ask...

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- Did it increase rural economic inequality?

- Through what mechanisms did these changes occur?

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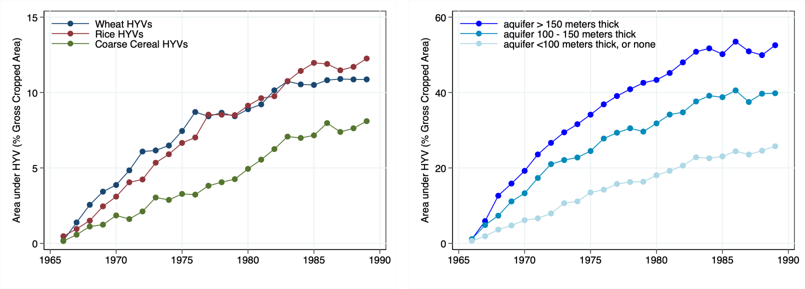
- Through what mechanisms did these changes occur?
    - Ongoing work, but...

Background: The Green Revolution in India

High-yielding varieties (HYVs), mostly rice and wheat, introduced for 1966-67 planting. Adoption trends vary with aquifer depth.



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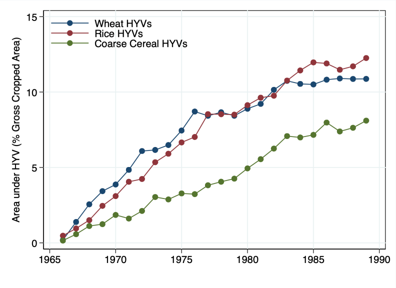

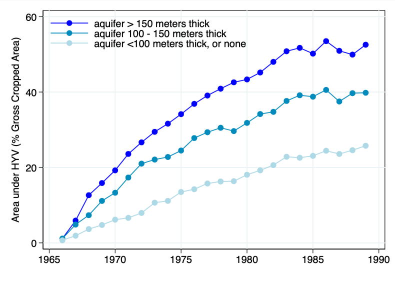

A data problem note up front. Above, I use district-level VDSA (Village Dynamics Studies in South Asia) through 1989.

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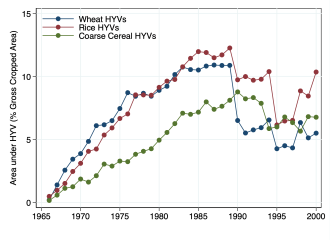

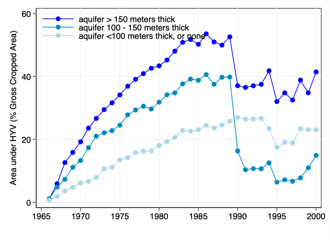

A data problem note up front. Above, I use district-level VDSA (Village Dynamics Studies in South Asia) through 1989. **This is what 1990-2000 looks like.**

Literature and Contribution

Disparate literature links ag productivity to rural inequality.

- New ag technologies often differentially benefit richer farmers (Goldstein & Udry 2008; Foster & Rosenzweig 2010; Hess, Jaimovich, & Schundeln 2021)
- And their impact on wages varies (Bustos, Caprettini, and Ponticelli, 2016)
- Increased ag productivity may influence family structure and farm division (Foster and Rosenzweig, 2002; Bardhan et al., 2014)
- Increased ag productivity $\rightarrow$ demand for education, non-ag sector spill-overs under *some* conditions (Foster & Rosenzweig 2001, 2004; Moscona 2019; Bustos, Caprettini & Ponticelli 2016, Hornbeck & Keskin 2015)

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We directly estimate the influence of a new ag technology on rural distribution of productive capital + rural income. *Seems that lack of non-ag sector spill-over trapped the poorest in low-profit ag, with accompanying welfare impacts.*

District-level VDSA Data

District-level data on agricultural conditions from the Village Dynamics in South Asia (VDSA) panel collected by ICRISAT

- Covers 311 districts across nineteen states, 1966-2011.
- Tracks the 1966 districts by apportioning data from subsequently-created districts.
- Data on cropping patterns, input use, area under high yielding varieties, irrigated area, etc.
- Holds the number of / acreage under marginal ($<$ 1ha), small (1-4 ha), medium (4-10 ha) and large ($>$10 ha) farms approx every 5 years.
- Critically, the VDSA begins in 1966, the year that HYVs were introduced to India.

ARIS-REDS Data

Using the household-level, ag-focused ARIS-REDS (dropping Jammu and Kashmir) to explore mechanisms.

- **1971.** 4,527 households in 259 villages in 100 districts of 17 states. In theory, representative of India's rural population.
- **1982.** Tracked 3,135 households outside of Assam (28% attrition) if intact or under 1971 head. Splits/splinters eligible for refresh along with new HHs (1,767 HHs).
- **1999.** Tracked 1982 households outside of Jammu and Kashmir, including splits/splinters within the village: 6,202 HHs (19% attrition). Refresh sampled new HHs only (1,271 HHs).
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NATIONAL FAMILY HEALTH SURVEY

Pooled individual-level maternal height and education data from two rounds of the National Family Health Survey (NFHS) conducted in 1998-1999 and 2015-2016.

- Nationally + urban/rural representative household surveys. 1998-99 representative at state level, 2015-2016 at district level.
- Maintain rural households only: 53,187 + 416,610 women
- Women 15-49 years old at time of survey. Women in the 2015/16 dataset born as early as 1965; women in the 1998/99 dataset as early as 1950.

ID Strategy

How did the roll-out of HYVs impact the number of / land share held by marginal, small, medium-sized, or large farmers?

$$Num_{dt}^{k} = \phi_0 + \phi_1 HYV_{dt-1} + \phi_2 X_{dt-1} + \delta_d + \delta_{st} + \epsilon_{dt}$$

Number of / share of ag land owned by farmers of size k in district d in year t, $Share_{dt}^{k}$. District-level prevalence of HYV adoption, HYV_{dt}, measured in share of gross cultivated land. District fixed effects δ_d, state-year fixed effects δ_{st}, and district-level concurrent and recent rainfall and temperature shocks, X_{dt}.

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ID Strategy: While roll-out across states not random, we follow Bharadwaj et al. (2018) to claim that within a state-year, district-level variation is plausibly (mostly?) exogenous. We find supporting evidence — only rainfall/temp shocks are correlated with HYV roll-out, not socioeconomic characteristics.

DiD Robustness Check

As a robustness check, we follow Sekhri & Shastry (2024) to examine how landholding patterns changed differentially over time in water-rich vs. water-scarce districts.

$$Num^k_{dt} = \zeta_0 + \Sigma_t \zeta_1^t A_d * t + \zeta_2 X_{dt-1} + \delta_d + \delta_t + \upsilon_{dt}$$

Each ζ_1^t provides a year-specific change in the marginal effect of having thicker ($\geq$ 100 meters) aquifers ($A_d = 1$), vis-a-vis the unidentified marginal effect in 1970.

If HYVs increases land inequality, marginal effect should increase for marginal and/or large farmers (i.e., ζ_1^t more positive over time) and decrease for medium-sized farmers (i.e., ζ_1^t more negative over time).

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Note: No data for a pre-trend check.

Other Rural Inequality Outcomes

I apply the original equation to rural distribution of productive farming assets, per capita income, female education levels.

$$Share^{k}_{dt} = \phi_0 + \phi_1 HYV_{dt-1} + \phi_2 X_{dt-1} + \delta_d + \delta_{st} + \epsilon_{dt}$$

Now, $Share^{k}_{dt}$ constructed from surveyed ARIS-REDS households within a district (d) and round (t), or from surveyed, rural NFHS women born in any given year (t) within a given district (d). I.e., share of surveyed households/ women in d and t falling within the 1st, 2nd, 3rd, or 4th (kth) income, height, or education quartile.

Number of Marginal Farms

	(1) # Marginal Farms	(2) # Small Farms	(3) # Medium Farms	(4) # Large Farms	(5) Farm Density
Panel A: VDSA					
HYV_t-1	70.61***	-23.23**	-14.49**	-0.0544	0.0616***
	(16.95)	(11.63)	(6.400)	(1.442)	(0.0236)
Outcome Mean	158.9	103.0	27.86	7.507	0.389
Observations	1696	1696	1696	1696	1698
Within R^2	0.0184	0.0250	0.0125	0.0121	0.00522
Panel B: ARIS-REDS					
HYV_t-1	5.193**	-2.006	0.677	0.858	4.722
	(2.191)	(3.071)	(1.168)	(0.856)	(3.318)
Outcome Mean	5.074	7.255	3.251	1.035	16.62
Observations	678	678	678	678	678
Within R^2	0.0216	0.0148	0.00778	0.00274	0.0183
District FE	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes

Outcomes cols 1-4: farm counts at district (village) level in Panel A (B). Col 5: farm count divided by district area (village farm count) in Panel A (B). Treatment: Proportion gross cultivated area under HYVs, lagged one year. Covariates: Rainfall and temperature shocks (lagged 1, 2, and 3 years). District-clustered standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Acreage under Marginal Farms

	(1) % Area to Marginal	(2) % Area to Small	(3) % Area to Medium	(4) % Area to Large
Panel A: VDSA				
HYV_t-1	0.0525***	-0.0637***	-0.0514***	0.0625***
	(0.0103)	(0.0235)	(0.0163)	(0.0212)
Outcome Mean	0.142	0.390	0.278	0.190
Observations	1551	1551	1551	1551
Within R^2	0.0337	0.0272	0.0344	0.0359
Panel B: ARIS-REDS				
HYV_t-1	0.0930	-0.265**	0.110	0.0614
	(0.0766)	(0.131)	(0.126)	(0.109)
Outcome Mean	0.138	0.387	0.314	0.161
Observations	677	677	677	677
Within R^2	0.0195	0.0250	0.0173	0.00138
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes

Outcomes: % of district (village-observed) agricultural area under each farm type (as observed) in Panel A (B). Treatment: Proportion gross cultivated area under HYVs, lagged one year. Covariates: Rainfall and temperature shocks (lagged 1, 2, and 3 years). District-clustered standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Robustness

Results are similar if: we examine the roll-out of wheat HYVs and rice HYVs alone (rice slightly larger impact), we separate districts by aquifer thickness, we examine concurrent HYV prevalence or prevalence lagged by 5 years, or we use the 1970-1980, -1986, -1990, -1995, or entire 1970-2000 sample.

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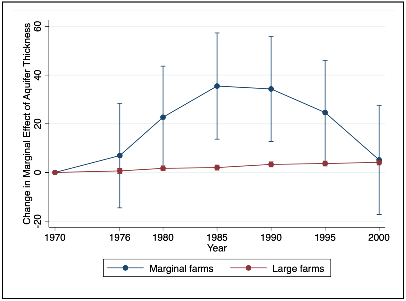
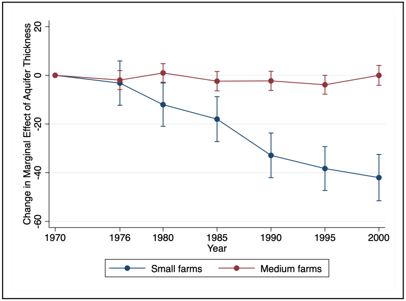
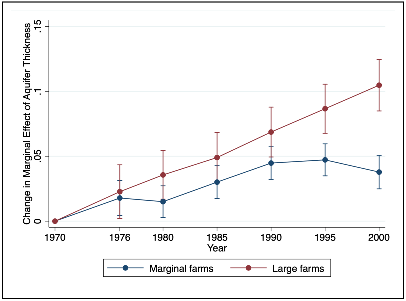
Results NOT driven by measurement error in 1990-2000 HYV acreage: results similar in the earlier data alone, when we dropping districts with more missing 1990-2000 data, and when we additionally drop likely-errored values. In fact, it seems like measurement error in HYV roll-out is biasing treatment effects towards zero, as it would if classical.

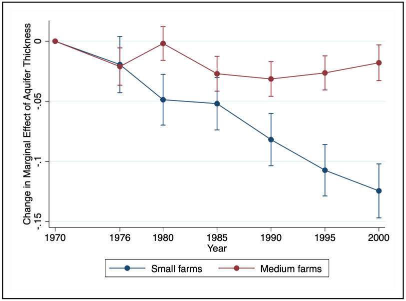
DiD Check: Number of Farms (VDSA)





DiD Check: Acreage under Farms (VDSA)





LAND VS. WELFARE

Livelihood diversification $\rightarrow$ distribution of other productive assets or total household income "much less inequitous than land or farm income distribution" (Bhalla and Chadha, 1982b)?

Moreover, medium-sized farmers – perhaps particularly near towns – may be exiting agriculture for potentially lucrative non-farm opportunities (Rao, Eberhard, and Bharadwaj 2022).

So while some Indian economists at the time did warn of distributional welfare impacts, seems like it could go either way...

FARMING ASSET DISTRIBUTION (ARIS-REDS)

	Quartile 1	Quartile 2	Quartile 3	Quartile 4
HYV_t-1	0.0279	-0.138	-0.204*	0.314*
	(0.157)	(0.156)	(0.117)	(0.167)
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	259	259	259	259
Within R^2	0.104	0.0417	0.0995	0.0574

Outcomes: District-level percent of **farmers** falling in the 1st, 2nd, 3rd, or 4th asset quartile (cols 1-4). Treatment: Proportion gross cultivated district area under rice/wheat HYVs, lagged one year. Sample: ARIS-REDS. Covariates: Rainfall and temperature shocks (lagged 1, 2, and 3 years). District-clustered standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1

Per Capita Income Distribution (ARIS-REDS)

	Quartile 1	Quartile 2	Quartile 3	Quartile 4
HYV_t-1	0.151	0.000744	-0.267***	0.115
	(0.126)	(0.0918)	(0.0929)	(0.101)
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	259	259	259	259
Within R^2	0.0582	0.0696	0.0677	0.0653

Outcomes: District-level percent of **households** falling in the 1st, 2nd, 3rd, or 4th per capita income quartile (cols 1-4). Treatment: Proportion gross cultivated district area under rice/wheat HYVs, lagged one year. Sample: ARIS-REDS. Covariates: Rainfall and temperature shocks (lagged 1, 2, and 3 years). District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

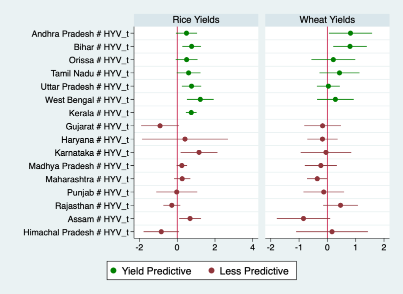
Female Education Distribution (rural NFHS)

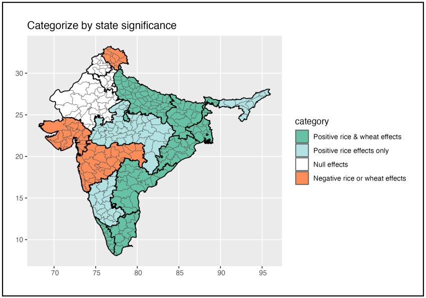
	Quartile 1	Quartile 2	Quartile 3	Quartile 4
HYV_t-1	0.0451	-0.0672***	-0.0461**	0.0685***
	(0.0324)	(0.0225)	(0.0227)	(0.0247)
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	13892	13892	13892	13892
Within R^2	0.00105	0.00275	0.00100	0.00317

Outcomes: District-level proportion of women reporting each level of education. Treatment: Proportion gross cultivated area under rice/wheat HYVs, lagged one year. Sample: District-year aggregates of NFHS pooled cross-section. Covariates: Rainfall and temperature shocks (lagged 1, 2, and 3 years). District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

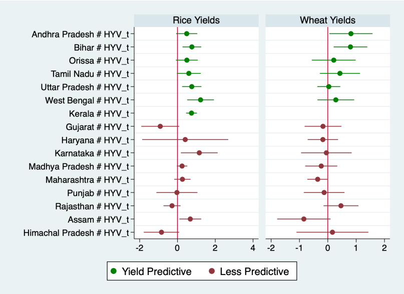
This is despite an overall positive impact on mean education levels. The results are similar if we break female education down by achievement levels.

VDSA HYV and VDSA Yields

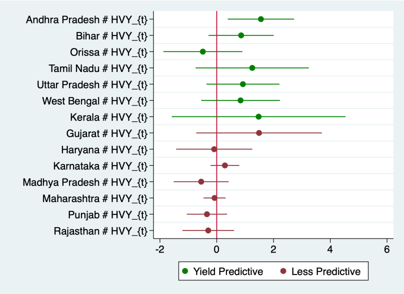




VDSA HYV and Endog ARIS-REDS Adoption



VDSA Yields



ARIS-REDS Adoption

HYV "EFFECT" BY STATE CATEGORIES

	ARIS-REDS	VDSA			
	Endog Adoption	Wheat Yields	Rice Yields	Coarse Cereal Yields	Calories per Cereal Hectare
Less Predictive States × HVY_t	-0.0940	-0.0423	0.219	0.0188	29.98**
	(0.181)	(0.137)	(0.139)	(0.0836)	(14.29)
Yield Predictive States × HVY_t	0.970***	0.343**	0.665***	0.205	94.25***
	(0.269)	(0.142)	(0.129)	(0.179)	(19.21)
District FE	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes
Observations	9910	7444	8280	8549	8765
Within R^2	0.0114	0.00826	0.0187	0.00529	0.0184

Outcomes: Endogenous adoption of HYV varieties in ARIS-REDS data (col 1), VDSA district-level yields in tons/hectare (cols 2-4), VDSA district-level calories per hectare in 100,000 kj/hectare (col 5). Treatment: Proportion gross cultivated area under rice/wheat HYVs. Covariates: Rainfall and temperature shocks (lagged 1, 2, 3 years). District-clustered errors. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Number of Farmers (VDSA)

	# Marginal Farms	# Small Farms	# Medium Farms	# Large Farms
Null/negative yield effect × HVY_t-1	88.84***	-16.71	-20.29*	-0.638
	(20.41)	(16.74)	(10.68)	(2.175)
Positive yield effect × HVY_t-1	39.75	-34.28**	-4.681**	0.933
	(29.44)	(13.40)	(2.369)	(1.240)
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	1696	1696	1696	1696
Within R^2	0.0201	0.0258	0.0149	0.0125

Outcomes: Number of farms within each size category. Treatment: Proportion gross cultivated area under HYVs, lagged one year. Sample: VDSA districts 1966-2000. Covariates: Rainfall and temperature shocks (lagged 1, 2, and 3 years). District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

AGRICULTURAL AREA SHARE (VDSA)

	% Area to Marginal	% Area to Small	% Area to Medium	% Area to Large
Null/negative yield effect × HVY_t-1	0.0504***	-0.0836**	-0.0570**	0.0902***
	(0.0118)	(0.0334)	(0.0231)	(0.0297)
Positive yield effect × HVY_t-1	0.0565***	-0.0261	-0.0408**	0.0103
	(0.0196)	(0.0246)	(0.0172)	(0.0214)
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	1551	1551	1551	1551
Within R^2	0.0338	0.0295	0.0348	0.0410

Outcomes: Percent of agricultural area held by farms within each size category. Treatment: Proportion gross cultivated area under HYVs, lagged one year. Sample: VDSA districts 1966-2000. Covariates: Rainfall and temperature shocks (lagged 1, 2, and 3 years). District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

FARMING ASSET DISTRIBUTION (ARIS-REDS)

	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Null/negative yield effect × HVY_t-1	-0.0256	-0.0142	-0.353**	0.393*
	(0.172)	(0.172)	(0.152)	(0.209)
Positive yield effect × HVY_t-1	0.129	-0.373	0.0796	0.164
	(0.282)	(0.264)	(0.214)	(0.288)
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	259	259	259	259
Within R^2	0.106	0.0499	0.110	0.0615

Outcomes: District-level percent of farmers falling in the 1st, 2nd, 3rd, or 4th per capita income quartile (cols 1-4). Treatment: Proportion gross cultivated district area under rice/wheat HYVs, lagged one year. Sample: ARIS-REDS. Covariates: Rainfall and temperature shocks (lagged 1, 2, and 3 years). District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Per Capita Income Distribution (ARIS-REDS)

	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Null/negative yield effect × HVY_t-1	0.221	0.00846	-0.244**	0.0152
	(0.147)	(0.121)	(0.108)	(0.133)
Positive yield effect × HVY_t-1	0.0183	-0.0139	-0.309*	0.304**
	(0.211)	(0.129)	(0.172)	(0.144)
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	259	259	259	259
Within R^2	0.0624	0.0697	0.0683	0.0776

Outcomes: District-level percent of farmers falling in the 1st, 2nd, 3rd, or 4th per capita income quartile (cols 1-4). Treatment: Proportion gross cultivated district area under rice/wheat HYVs, lagged one year. Sample: ARIS-REDS. Covariates: Rainfall and temperature shocks (lagged 1, 2, and 3 years). District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Female Education Distribution (rural NFHS)

	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Null/negative yield effect × HVY_t-1	0.0297	-0.0619*	-0.0466	0.0796**
	(0.0445)	(0.0331)	(0.0343)	(0.0361)
Positive yield effect × HVY_t-1	0.0604	-0.0725**	-0.0455	0.0576*
	(0.0468)	(0.0304)	(0.0298)	(0.0336)
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	13892	13892	13892	13892
Within R^2	0.00109	0.00276	0.00100	0.00323

Outcomes: District-level proportion of women reporting each level of education. Treatment: Proportion gross cultivated area under HYVs, lagged one year. Sample: District-year aggregates of NFHS pooled cross-section. Covariates: Rainfall and temperature shocks (lagged 1, 2, and 3 years). District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Likelihood of Being Marginal

	(1) Base Year Marginal: Marginal	(2) Base Year Small: Marginal	(3) Base Year Medium: Marginal	(4) Base Year Large: Marginal
Less yield predictive × Δ HVY_t	0.433	-0.0440	-0.0453	-0.764***
	(0.431)	(0.149)	(0.0897)	(0.249)
Yield predictive × Δ HVY_t	0.467*	0.724***	-0.213	-0.868***
	(0.256)	(0.267)	(0.240)	(0.241)
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	1301	2622	1658	552
Within R^2	0.0106	0.00971	0.00439	0.0652

Outcome: Indicator for owning a marginal farm (<1 hectare) in 1982 or 1999. ΔHYV_t provides the change in the proportion of gross cropped area dedicated to HYVs between 1971 and 1982 (1982 obs) or between 1982 and 1999 (1999 obs). Sample: ARIS-REDS panel and refresh households in 1982 and 1999 if in the base year (1971 or 1982, respectively) the household: was landless (col 1), owned agricultural land (col 2), owned 0-1 hectare of agricultural land (col 3), owned 1-10 hectares of agricultural land (col 4), owned $>$ 10 hectares of agricultural land (col 5). District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

LAND ACQUISITION BY LANDLESS

	(1) Own land	(2) Own $<$ 1 ha	(3) Own $\geq$ 1 ha
Less yield predictive $\times$ Δ HVY_t	-0.527**	-0.492***	-0.0349
	(0.254)	(0.165)	(0.219)
Yield predictive $\times$ Δ HVY_t	0.922***	0.780***	0.142
	(0.226)	(0.178)	(0.114)
District FE	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes
Observations	1566	1566	1566
Within R^2	0.0213	0.0195	0.00359

Outcome: Indicator for owning land. Sample: ARIS-REDS households in 1982 and 1999 if the household owned no land in the previous round (1971 for 1982, 1982 for 1999). ΔHYV_t provides the change in the proportion of gross cropped area dedicated to HYVs since 1971. District-clustered errors. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Likelihood of Farm/Household Dissolution

	(1) Marginal Farms: Exit Panel	(2) Small Farms: Exit Panel	(3) Medium Farms: Exit Panel	(4) Large Farms: Exit Panel
Less yield predictive × Δ HVY_t	-0.168 (0.323)	0.234 (0.157)	-0.191 (0.153)	-0.118 (0.251)
Yield predictive × Δ HVY_t	-0.721** (0.344)	-0.738** (0.345)	-0.694 (0.507)	1.370*** (0.485)
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	938	1647	902	269
Within R^2	0.0130	0.0125	0.0194	0.0225

Outcome: Indicator for exiting the panel in 1982 or 1999. ΔHYV_t provides the change in the proportion of gross cropped area dedicated to HYVs between 1971 and 1982 (1982 obs) or between 1982 and 1999 (1999 obs). Sample: ARIS-REDS panel and refresh households in 1982 and 1999 if in the base year (1971 or 1982, respectively) the household: was landless (col 1), owned agricultural land (col 2). In both columns 1982 households with a household head over 40 in 1971 were dropped, since these households are likely to have exited the panel due to dissolution rather than migration (Foster and Rosenzweig, 2002). District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Agricultural Wages

	Male	Female	Male	Female
HVY_t-1	-0.140	-0.421		
	(0.268)	(0.338)		
Null/negative yield effect × HVY_t-1			-0.552	-0.308
			(0.386)	(0.445)
Positive yield effect × HVY_t-1			0.493	-0.613*
			(0.346)	(0.363)
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	618	595	618	595
Within R^2	0.0225	0.0107	0.0341	0.0113

Outcome: Village-level agricultural wage rate for men (cols 1, 3) and women (cols 2, 4). Sample: ARIS-REDS villages. District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

NON-AGRICULTURAL WAGES

	Male	Female	Male	Female
HVY_t-1	-1.338***	-1.078		
	(0.498)	(0.772)		
Less yield predictive × HVY_t-1			-1.264**	-1.196
			(0.630)	(0.945)
Yield predictive × HVY_t-1			-1.497**	-0.702
			(0.617)	(1.057)
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	468	338	468	338
Within R^2	0.0794	0.112	0.0796	0.113

Outcome: Village-level non-agricultural wage rate for men (cols 1, 3) and women (cols 2, 4). Sample: ARIS-REDS villages. District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Non-Agricultural Activities

	Landless			Landed		
	(1) Non-Ag Wages	(2) Non-Ag Salary	(3) Non-Ag Self-Emp	(4) Non-Ag Wages	(5) Non-Ag Salary	(6) Non-Ag Self-Emp
Null/negative yield effect × HVY_t-1	-0.511**	0.286	0.0378	-0.286***	-0.0338	0.0208
	(0.235)	(0.206)	(0.244)	(0.0889)	(0.0619)	(0.106)
Positive yield effect × HVY_t-1	0.339**	-0.0383	-0.0643	-0.0464	-0.0971	-0.0979
	(0.170)	(0.105)	(0.198)	(0.114)	(0.113)	(0.201)
Outcome Mean	0.227	0.170	0.343	0.0963	0.149	0.297
District FE	Yes	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3783	3783	3783	11265	11265	11265
Within R^2	0.00891	0.00503	0.00539	0.00632	0.000962	0.00214

Outcome: Indicator for household having income from non-agricultural wages (cols 1, 5), from salary (cols 2, 6), from non-agricultural self employment (3, 7), or from any of those 3 sources (cols 4, 8). Sample: ARIS-REDS panel and refresh households if the household is landless (col 1-4), or owns agricultural land (col 5-8). District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Thanks!

Thanks for your time and attention and thoughts!

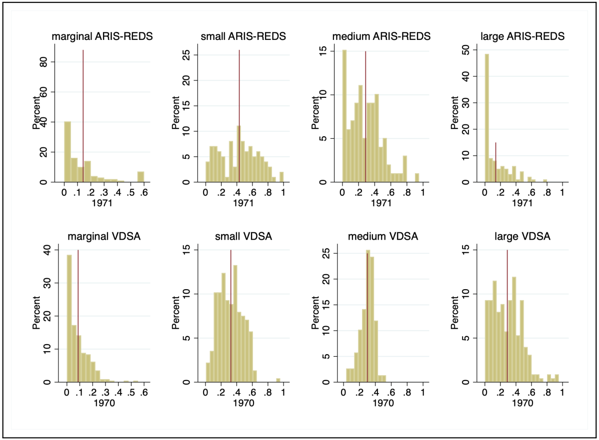
ARIS-REDS Data

- **1971.** Additional Rural Incomes Survey (ARIS): 4,527 households in 259 villages in 100 districts of 17 states. In theory, representative of India's rural population, oversampling villages with greater HYV uptake and wealthier (larger-farm) households. Weights provided.
- **1982.** Rural Economic and Demographic (REDS) survey: tracked 3,135 panel households outside of Assam. Tracked HHs if either intact or under 1971 head; split-offs not tracked.
  - Attrition (28%): '71 head died and the HH splintered, entire HH left village, HH refused/absent (rare).
  - Refresh (1,767 HHs): *did* sample spit-offs and splinter HHs + new households not in the 1968 listing data.
- **1999.** Tracked 1982 households outside of Jammu and Kashmir, including splits / splinter HHs residing in the same village: 6,202 HHs.
  - Attrition (19%): entire HH left village, HH refused/absent.
  - Refresh (1,271 HHs): new households not in the 1981 listing data.

- District strata: Intensive Agricultural Development Program (IADP), villages within the Intensive Agricultural Area Program (IAAP), and all other villages.
- Income strata: H ($\geq$ Rs 6,000), M (Rs 3,600-6,000), L ($<$ Rs 3,600). Approx 20 HHs selected per village, oversampling H- and M-income HHs such that no L-income HHs were sampled if $>$ 20 H- and M-income HHs existed in village.
- In theory, provided 1971 weights should up-weight poorer households and down-weight richer households such that a nationally representative sample is obtained.

Back

These weights don't → a nationally-representative land distribution...



District-level % Ag Land Held by Farm Size

Back

	1966-1971	1972-1981	1982-2000	All
Rainfall this year (cv mm)	0.00555**	0.00309***	0.00396**	0.00400***
	(0.00215)	(0.00116)	(0.00171)	(0.00119)
Rain last year (cv mm)	0.00463**	-0.000419	0.00151	0.00143
	(0.00228)	(0.00114)	(0.00156)	(0.00106)
Rain two years ago (cv mm)	0.00597**	-0.000983	-0.000261	0.000914
	(0.00241)	(0.00108)	(0.00170)	(0.00111)
Temperature this year (cv C)	-0.00323	-0.00548**	0.00387	-0.00134
	(0.00328)	(0.00227)	(0.00361)	(0.00250)
Temperature last year (cv C)	-0.000693	0.00115	-0.00181	-0.00308
	(0.00330)	(0.00212)	(0.00296)	(0.00191)
Temperature two years ago (cv C)	-0.00173	0.00377*	-0.00594*	-0.00474**
	(0.00274)	(0.00209)	(0.00338)	(0.00232)
Population density (log person/hectare)	0.00770	-0.00925	0.0106	-0.0354
	(0.0790)	(0.0143)	(0.0401)	(0.0324)
Urban population (% of total)	-0.380	-0.0500	0.0821	0.0224
	(0.811)	(0.184)	(0.131)	(0.107)
Gender ratio (male:female)	0.496*	-0.105	0.557	0.0800
	(0.262)	(0.333)	(0.424)	(0.219)
Literacy rate (%)	0.246	0.0778	0.199	0.248*
	(0.228)	(0.104)	(0.177)	(0.128)
Literacy gender ratio (male:female)	0.0387	0.0250	-0.0103	-0.00672
	(0.0350)	(0.0186)	(0.0168)	(0.0114)
District and State-Year Fixed Effects	Yes	Yes	Yes	Yes
Weather Shocks Joint Significance	0.0300	0.000	0.000	0.000
Socioeconomic Var Joint Significance	0.190	0.500	0.560	0.370
Observations	1197	2810	4273	8295
R^2	0.0323	0.0134	0.00954	0.0116

Outcome: Proportion gross cultivated area under HYVs. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Farm Area Distribution (ARIS-REDS Panel)

	% Families Landless	% Area to Marginal	% Area to Small	% Area to Medium	% Area to Large
HYV_t-1	-0.0168	0.00928	0.274*	-0.443***	0.159
	(0.131)	(0.0467)	(0.154)	(0.135)	(0.142)
District FE	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes
Observations	269	269	269	269	269
Within R^2	0.00806	0.0399	0.0783	0.0771	0.0206

Weights: 1971 household weights applied to all rounds. Outcomes: District-level proportion agricultural land held by each farmer category, within the ARIS-REDS dataset (panel + refresh). Treatment: Proportion gross cultivated area under HYVs, lagged one year. Sample: VDSA districts 1966-2000. Covariates: Rainfall and temperature shocks (lagged 1, 2, and 3 years). District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

A 25% increase in acreage under HYVs leads to a 6.8 pp increase in area under small farms, and an 11.1 pp decrease in the area under medium farms. An insignificant 4.0 pp increase in area under large farms. Back

Farm Numbers (ARIS-REDS)

	# Marginal Farms	# Small Farms	# Medium Farms	# Large Farms
HYV_t-1	4.238	20.30***	-10.28*	2.186
	(3.598)	(5.808)	(6.059)	(3.343)
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	271	271	271	271
Within R^2	0.0476	0.0840	0.0779	0.0197

Outcomes: District-level proportion agricultural land held by each farmer category, within the ARIS-REDS dataset (panel + refresh). Treatment: Proportion gross cultivated area under HYVs, lagged one year. Sample: VDSA districts 1966-2000. Covariates: Rainfall and temperature shocks (lagged 1, 2, and 3 years). District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Back

Farm Area Distribution in ARIS-REDS Survey Years (VDSA)

	% Area to Marginal	% Area to Small	% Area to Medium	% Area to Large
HYV_t-1	0.0860***	-0.0892**	-0.111***	0.114***
	(0.0172)	(0.0377)	(0.0270)	(0.0360)
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	594	594	594	594
Within R^2	0.103	0.0712	0.132	0.112

Outcomes: Proportion operational land-holdings held by each farmer category. Treatment: Proportion gross cultivated area under HYVs, lagged one year. Sample: VDSA districts 1970, 1980, 2000. Covariates: Rainfall and temperature shocks (lagged 1, 2, and 3 years). District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Back

Farmland Distribution in ARIS-REDS Survey Districts (VDSA)

	% Area to Marginal	% Area to Small	% Area to Medium	% Area to Large
HYV_t-1	0.0634***	-0.0854**	-0.0575**	0.0795**
	(0.0206)	(0.0393)	(0.0253)	(0.0365)
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	511	511	511	511
Within R^2	0.0510	0.0669	0.0303	0.0460

Outcomes: Proportion operational land-holdings held by each farmer category. Treatment: Proportion gross cultivated area under HYVs, lagged one year. Sample: VDSA districts observed in ARIS-REDS survey, 1966-2000. Covariates: Rainfall and temperature shocks (lagged 1, 2, and 3 years). District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Back

Mean Education, Height Effects (rural NFHS)

	Height	Years Edu
HYV_t-1	0.373*	0.756***
	(0.191)	(0.266)
District FE	Yes	Yes
State-Year FE	Yes	Yes
Observations	397302	405838
Within R^2	0.0000298	0.000183

Outcomes: Height in cm (col 1), educational attainment in years (col 2). Treatment: Proportion gross cultivated area under HYVs, lagged one year. Sample: NFHS pooled cross-section. Covariates: Rainfall and temperature shocks (lagged 1, 2, and 3 years). District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Back

Female Education Distribution (rural NFHS)

	No Education	Primary Education	Secondary Education	Higher Education
HYV_t-1	0.0451	-0.0673***	-0.00898	0.0315**
	(0.0324)	(0.0225)	(0.0260)	(0.0143)
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	13892	13892	13892	13892
Within R^2	0.00105	0.00275	0.000506	0.00170

Outcomes: District-level proportion of women reporting each level of education. Treatment: Proportion gross cultivated area under HYVs, lagged one year. Sample: District-year aggregates of NFHS pooled cross-section. Covariates: Rainfall and temperature shocks (lagged 1, 2, and 3 years). District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Back

Female Height Distribution (rural NFHS)

	Quartile 1	Quartile 2	Quartile 3	Quartile 4
HYV_t-1	-0.0136	-0.00718	0.00184	0.0191
	(0.0187)	(0.0185)	(0.0174)	(0.0259)
District FE	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes
Observations	13892	13892	13892	13892
Within R^2	0.000656	0.000423	0.000989	0.000370

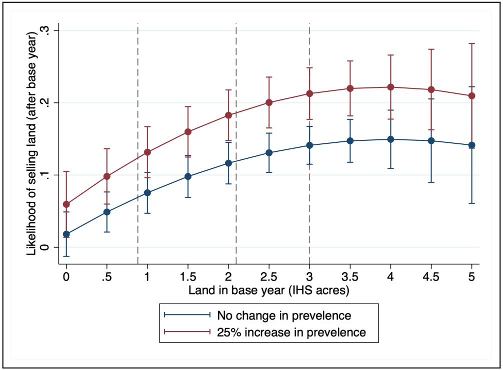
Outcomes: District-level proportion of women in the 1st, 2nd, 3rd, or 4th height quantile. Treatment: Proportion gross cultivated area under HYVs, lagged one year. Sample: District-year aggregates of NFHS pooled cross-section. Covariates: Rainfall and temperature shocks (lagged 1, 2, and 3 years). District-clustered standard errors in parenthesis. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Land Selling

	(1)	(2)	(3)
Δ HYV_t	0.246**	0.165	
	(0.101)	(0.128)	
Land owned in base year (IHS acres)		0.0655***	
		(0.0152)	
(Land owned)^2		-0.00817*	
		(0.00417)	
Land owned × Δ HYV_t		0.0688	
		(0.0965)	
(Land owned)^2 × Δ HYV_t		-0.00945	
		(0.0250)	
Less yield predictive × Δ HVY_t			0.126
			(0.126)
Yield predictive × Δ HVY_t			0.520***
			(0.101)
District FE	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes
Observations	5622	5415	5622
Within R^2	0.0113	0.0401	0.0132

Outcome: Binary indicator for selling land between 1971 and 1982 (when 1982 is the base year) or between 1982 and 1999 (when 1982 is the base year). Sample: ARIS-REDS households, if they owned land in the base year. District-clustered errors. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Land Selling



Land Purchasing

	(1) All	(2) Base Year Landless	(3) All	(4) All	(5) Base Year Landless
Δ HYV_t	0.000588	0.0536	-0.0896		
	(0.0661)	(0.112)	(0.0908)		
Land owned in base year (IHS acres)			-0.0336***		
			(0.0123)		
(Land owned)^2			0.00423		
			(0.00287)		
Land owned × Δ HYV_t			0.117*		
			(0.0681)		
(Land owned)^2 × Δ HYV_t			-0.0270*		
			(0.0159)		
Less yield predictive × Δ HVY_t				-0.0285	-0.0423
				(0.0479)	(0.0968)
Yield predictive × Δ HVY_t				0.0575	0.198
				(0.160)	(0.244)
District FE	Yes	Yes	Yes	Yes	Yes
State-Year FE	Yes	Yes	Yes	Yes	Yes
Observations	8553	2931	6922	8553	2931
Within R^2	0.00193	0.00538	0.00643	0.00203	0.00613

Outcome: Binary indicator for purchasing land between 1971 and 1982 (when 1982 is the base year) or between 1982 and 1999 (when 1982 is the base year). Sample: ARIS-REDS households. District-clustered errors. *** $p<0.01$, ** $p<0.05$, * $p<0.1$