Supplementary Appendix A Representative images of hillside irrigation schmes in Rwanda

Figure S1: Karongi 12 hillside irrigation scheme

Supplementary Appendix B Main variables appendix

Household variables: All household variables are constructed from the baseline.

- *HHH female*: Indicator that the household head is female.
- *HHH age*: Age of the household head.
- *HHH completed primary*: Indicator that the household head completed primary.
- *HHH worked off farm*: Indicator that the household head worked off farm.
- *# of plots*: Number of plots reported as managed by the household. Includes plots rented in, plots owned and cultivated in the past year, and plots rented out.
- *# of HH members*: Number of members of the household.

- *# of HH members (15-64)*: Number of members of the household between age 15 and 64.
- *# of HH members who worked off farm*: Number of members of the household who worked off farm.
- *Housing expenditures*: Expenditures over the past year on housing and furnishing. Winsorized at the 99th percentile.
- *Asset index*: First principal component of log number of assets-by-category owned and an indicator for positive number of assets-by-category owned, where the categories are cows, goats, pigs, chickens, radios, mobile phones, pieces of furniture, bicycles, and shovels. Standardized to be mean 0 and standard deviation 1, with positive values indicating more assets.
- *Food security index*: First principal component of log days in the past week of consumption of food item-by-category and an indicator for any consumption of food item-by-category. In baseline, categories are flour, bread, rice, meat and fish, poultry and eggs, dairy products, cooking oil, fruits, beans, vegetables, plantains and cassava and potatoes, juice and soda, sugar and honey, salt and spices, meals prepared outside home, and groundnut and other oilseed flour. In follow up surveys, categories are flour, bread, cakes and chapati and mandazi, rice, small fish, meats and other fish, poultry and eggs, dairy products, peanut oil, palm oil and other cooking oil, avocados, other fruits, beans, tomato, onion, other vegetables, plantains, Irish potatoes, sweet potatoes, sugar, salt, local banana beer at home, groundnut flour. Standardized to be mean 0 and standard deviation 1, with positive values indicating more consumption.
- *Overall index*: Index constructed following Anderson (2008) using housing expenditures, asset index, and food security index.
- *Fees paid*: Total water usage fees paid in 2017 Rainy 1 and 2.

Plot variables: All plot variables are constructed from the baseline.

- *Command area*: Indicator that plot located in command area, equal 1 if any share of the plot is inside of the command area. Calculated from plot map.
- *Distance to boundary*: Distance from plot boundary to command area boundary, 0 for plots whose plot map intersects the boundary. Positive for plots that are inside the command area, negative for plots that are outside the command area. Calculated from plot map.
- *Area*: Area in hectares. Calculated from plot map.

- *Water user group*: Water user groups that the plot is located in, calculated from plot map. If the plot intersects multiple water user group boundaries, the water user group in which the largest share of the plot's area is contained. Missing for plots that are outside the command area.
- *Nearest water user group*: For plots inside the command area, the water user group. For plots outside the command area, the water user group whose boundary the boundary of the plot is the shortest distance from. Calculated from plot map.
- *Terraced*: Indicator that the plot was terraced.
- *Elevation*: Elevation of plot in meters. Calculated from plot map.
- *Slope*: Maximum plot grade. Calculated from plot map.

Plot-season variables: All plot-season variables are constructed from the baseline when used in balance tables. Variables related to attrition are observed at plot-season level when used as outcomes in regressions testing for differential attrition.

- *Own plot*: Indicator that the surveyed cultivator owns the plot. 0 when the surveyed cultivator rents in the plot.
- *Owned plot >5 years*: Indicator that the surveyed cultivator had owned the plot for at least 5 years.
- *Rented out to farmer*: Indicator that the surveyed cultivator rented out the plot to another farmer.
- *Rented out to commercial farmer*: Indicator that the plot was rented out to a commercial farmer.
- *HH attrition*: Plot-season indicator that the household associated with the plot was not reached for the survey.
- *Transaction (not tracked)*: Plot-season indicator that the plot was sold, rented out, or no longer rented in, and the new household responsible for the plot was not successfully followed up with.
- *Tracked*: Plot-season indicator that the plot was sold, rented out, or no longer rented in, and the new household responsible for the plot was successfully followed up with and asked questions on agricultural production on the plot.
- *Missing*: Plot-season indicator that agricultural production data is missing for that plot. Sum of variables HH attrition, Rented out to commercial farmer, and Transaction (not tracked).

Agricultural variables

- *Cultivated*: Plot-season indicator for any cultivation. All other agricultural variables are set to 0 when no cultivation takes place.
- *Irrigated*: Plot-season indicator for any irrigation use (i.e., adoption of irrigation); set to 0 when no cultivation takes place.
- *Days irrigated*: Plot-season number of days irrigation was used; set to 0 when no cultivation takes place unless otherwise specified.
- *Days w/o enough water*: Plot-season count of number of days household reported not having sufficient water for irrigation, missing when household did not irrigate that plot-season.
- *Horticulture*: Plot-season indicator for any horticulture cultivated. As horticultural crops are annuals, this will include activities associated with planting, growing, and harvesting; set to 0 when no cultivation takes place.[S1]
- *Banana*: Plot-season indicator for any bananas cultivated. While bananas are a perennial, their cultivation cycle is relatively short and requires an annual adoption and readoption decision. Hence this variable refers to any activities associated with planting, growing, or harvesting, and need not include all three; set to 0 when no cultivation takes place.
- *HH labor/ha*: Plot-season sum of household labor use, divided by plot area. Winsorized at the 99th percentile; set to 0 when no cultivation takes place.
- *Input expenditures/ha*: Plot-season sum of expenditures on non-labor inputs, divided by plot area. Winsorized at the 99th percentile; set to 0 when no cultivation takes place.
- *Hired labor expenditures/ha*: Plot-season sum of expenditures on hired labor, divided by plot area. Winsorized at the 99th percentile; set to 0 when no cultivation takes place.
- *Hired labor (days)/ha*: Plot-season sum of hired labor use, divided by plot area. Winsorized at the 99th percentile; set to 0 when no cultivation takes place.
- *Wage*: Plot-season ratio of hired labor expenditures/ha to hired labor (days)/ha, set to missing when hired labor (days)/ha is 0.
- *Price*: Prices are calculated at the District-crop-season level, as the median of plot-crop-season reported sales divided by reported kilograms sold. Prices are set to missing when there are less than 10 observations that District-crop-season

[S1] In Table 1, an alternative definition of crop choice is used, where a crop indicator indicates that crop is the primary crop cultivated that plot-season.

and either more than two District-crop-seasons with at least 10 observations that District-crop-survey or at least 30 observations that District-crop-survey; these cut-off points were chosen to maximize inclusion of prices judged subjectively to be reasonable, and maximize exclusion of prices judged subjectively to be not reasonable.

- *Yield*: Plot-season sum of prices times harvested quantities. Yields are missing when all crops cultivated that plot-season have missing prices or missing harvested quantities. When multiple crops are grown on a plot-season and some have observed prices and harvested quantities, those with missing prices or quantities are treated as 0 production and we impute 0 value when no cultivation takes place on the plot. After this procedure 3.6% of rainy season observations and 5.3% of dry season observations in our discontinuity sample have missing yields. Winsorized at the 99th percentile.
- *Sales/ha*: Plot-season total reported sales, divided by area. Set to 0 when no cultivation takes place. Winsorized at the 99th percentile.
- *Sales share*: Sales/ha divided by yield, equal to 1 when reported sales/ha is greater than yield. Set to 0 when no cultivation takes place.
- *Profits/ha (Shadow wage = 0 RwF/day)*: Yield minus hired labor expenditures/ha minus input expenditures/ha; set to 0 when no cultivation takes place.
- *Profits/ha (Shadow wage = 800 RwF/day)*: Yield minus hired labor expenditures/ha minus input expenditures/ha minus 800 times HH labor/ha; set to 0 when no cultivation takes place.

Experimental variables: Additional details on these variables are in Appendix L.

- *Assigned minikit*: Indicator that household was assigned to receive a minikit.
- *Minikit saturation*: Saturation of minikits assigned for the Water User Group of the plot.
- *Minikit takeup*: Indicator that the household reported using a minikit.
- *Zone*: The Zone in which the plot's Water User Group is located in. The plots in our survey are located in 239 Water User Groups grouped into 33 Zones.
- *O&M treatment*: O&M treatment status of the Water User Group of the plot.
- *# of lotteries entered, minikits*: Number of lotteries for minikits the household was entered into.

Landsat variables: Additional details on these variables are in Appendix B.

- *100 * NDVI*: Plot-by-satellite image NDVI times 100, observations with cloud cover set to missing.

- *100 * NDVI (pre-2009)*: Plot average NDVI in satellite images from January 1999 through December 2008.
- *100 * NDVI (pre-2009, Dry)*: Plot average NDVI in satellite images from January 1999 through December 2008, restricting to June through August.
- *100 * NDVI (pre-2009, Rainy)*: Plot average NDVI in satellite images from January 1999 through December 2008, restricting to September through May.

Supplementary Appendix C Intensive and extensive margins

To complement the analysis in Section 3, we separate the impacts of sample plot access to irrigation, on both sample plots and largest other plots, into intensive and extensive margin effects. To do so, we compare estimated coefficients in Tables 4 and 8 to the same specifications with the inclusion of controls for cultivation, horticulture, and bananas. As crop fixed effects are a "bad control" (Angrist & Pischke, 2008), which introduces selection bias, we interpret these results as suggestive. However, we anticipate that selection conditional on crop choice should bias us towards finding no intensive margin effect on largest other plots, as the particularly constrained households switching out of horticulture in response to the sample plot shock are likely to be the households who used less labor and inputs. These results are presented in Table S1; the effects we document in Section 3 are driven by the shift to dry season horticulture, as effects on sample plots all but disappear controlling for crop choice. Shifting to largest other plots, Table S1 suggests that much of the effect of the sample plot shock on labor and input use on largest other plots is driven by intensive margin responses, as coefficients on household labor and inputs fall by only 27% - 38%. Combined with our results on irrigation use and horticulture, this suggests that households respond to the sample plot shock on both the intensive and extensive margins on their largest other plot.

Table S1: Impacts of access to irrigation are mostly explained by transition to horticulture from bananas, but impacts of sample plot shock on largest other plot are on both extensive and intensive margins

	Dry season, Discontinuity sample									
	SP							LOP		
	HH labor/ ha	Input exp./ha	Hired labor exp./ha	Yield	Sales /ha	Profits/ha Shadow wage = 0	Profits/ha Shadow wage = 800	HH labor/ ha	Input exp./ha	Hired labor exp./ha
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
RDD (Site-by-season FE, Specifications 1 & 3), Crop FE										
SP CA	28.7	1.2	1.4	29.1	22.5	27.8	10.7	-26.4	-4.1	-1.5
	(14.1)	(1.2)	(1.7)	(18.0)	(11.2)	(16.7)	(15.7)	(14.7)	(2.1)	(2.0)
	[0.042]	[0.311]	[0.432]	[0.105]	[0.045]	[0.097]	[0.494]	[0.073]	[0.052]	[0.442]
Effect w/o Crop FE	71.6	6.1	3.2	64.8	50.2	56.3	2.2	-36.4	-5.8	-1.9
SFE (Spatial FE, Specifications 2 & 4), Crop FE										
SP CA	27.5	-1.2	0.7	10.4	7.0	12.1	0.4	-22.6	-4.5	0.5
	(15.3)	(1.4)	(2.3)	(23.1)	(13.7)	(21.5)	(19.7)	(17.5)	(2.2)	(2.1)
	[0.073]	[0.416]	[0.768]	[0.654]	[0.607]	[0.573]	[0.984]	[0.197]	[0.036]	[0.802]
Effect w/o Crop FE	79.2	4.6	2.5	48.1	42.8	42.4	-8.5	-36.2	-6.6	-0.1
# of observations	2,427	2,430	2,430	2,307	2,430	2,307	2,305	2,094	2,097	2,097
# of clusters	173	173	173	173	173	173	173	165	165	165

Supplementary Appendix D Imputing profits under rentals to commercial farmers

In Appendix H.1, we demonstrated access to irrigation causes some plots to be rented out to commercial farmers producing export crops. We argued this would, if anything, bias down our estimates of the direct effects of access to irrigation in Section 3, as commercial farmers are likely to have much higher production and farm more intensively. As an alternative approach to evaluate the role of rentals out to commercial farmers in the interpretation of our results on the impacts of irrigation in Section 3, we define profits when plots are rented out to commercial farmers (which we currently code as missing) to be the seasonal rental rate paid by commercial farmers to the household. This eliminates differential attrition of sample plots in the command area due to rentals to commercial farmers. Estimated impacts on profits with this alternative coding provide a lower bound on the total direct impacts of irrigation, in the sense that they do not account for any profits earned by the commercial farmers. The average seasonal rent paid by commercial farmers is 74,000 RwF/ha; for reference, on sample plots outside the command area, dry season profits when household labor is not priced and is priced at the market wage are 75,000 RwF/ha and 32,000 RwF/ha, respectively.

We present estimates of Specifications 1 and 2 in Table S2 for profits with household labor not priced and priced at the market wage, either leaving profits as missing when plots are rented out to commercial farmers (as in Table 4) or defining profits as rental rates when plots are rented out to commercial farmers. We find that our dry season estimates of impacts on profits when household labor is not priced remain essentially identical, while our dry season estimates of impacts on profits when household labor is priced at market wages increase by 3,000 - 6,000 RwF/ha and remain statistically insignificant and economically small; our rainy season estimates are similarly unaffected.

Table S2: Profits from access to irrigation depend on household's shadow wage, whether or not rent from commercial farmers is accounted for

(a) Dry season

	SP, Dry season, Discontinuity sample			
	Profits/ha		Profits + comm. farmer rent/ha	
	Shadow wage		Shadow wage	
	= 0	= 800	= 0	= 800
	(1)	(2)	(3)	(4)
RDD (Site-by-season FE, Specification 1)				
SP CA	56.3	2.2	57.0	8.0
	(20.9)	(16.5)	(19.8)	(15.8)
	[0.007]	[0.893]	[0.004]	[0.615]
SFE (Spatial FE, Specification 2)				
SP CA	42.4	-8.5	41.4	-5.1
	(24.4)	(20.2)	(23.4)	(19.7)
	[0.082]	[0.676]	[0.077]	[0.795]
# of observations	2,307	2,305	2,515	2,513
# of clusters	173	173	173	173
Control mean	75.2	31.6	74.7	31.7

(b) Rainy seasons

	SP, Rainy seasons, Discontinuity sample			
	Profits/ha		Profits + comm. farmer rent/ha	
	Shadow wage		Shadow wage	
	= 0	= 800	= 0	= 800
	(1)	(2)	(3)	(4)
RDD (Site-by-season FE, Specification 1)				
SP CA	-22.7	-33.4	-20.7	-25.4
	(28.4)	(26.7)	(27.1)	(25.8)
	[0.425]	[0.211]	[0.444]	[0.326]
SFE (Spatial FE, Specification 2)				
SP CA	-23.2	-31.3	-22.7	-23.7
	(27.3)	(32.3)	(25.9)	(31.1)
	[0.395]	[0.333]	[0.382]	[0.446]
# of observations	3,922	3,915	4,256	4,249
# of clusters	173	173	173	173
Control mean	242.0	59.0	239.5	58.8

Supplementary Appendix E Impacts of access to irrigation using engineering boundary

In one of the two sites used in our analysis of the impacts of access to irrigation, we georeferenced an engineering schematic of the hillside irrigation scheme, and used this drawing as an alternative to the realized boundary. In that site, 92% of plots would have the same assignment in our data to access to irrigation based on the engineering drawing and in the ultimately-constructed irrigation infrastructure. To test the robustness of our analysis in Section 3 to the use of this alternative boundary, we estimate Specifications 1 and 2 in this site, either using the boundary in the engineering drawing or using the realized boundary, and present these results in Table S3. While our sample size becomes much smaller when we restrict to this site, our estimates are robust to the use of this alternative measure of the boundary.

Table S3: Impacts of access to irrigation are robust to using engineering drawing

	SP, Dry season, K12 engineering drawing discontinuity sample										
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha	Yield	Sales /ha	Profits/ha Shadow wage = 0	Profits/ha Shadow wage = 800
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Engineering drawing RDD (Site-by-season FE, Specification 1)											
SP CA	0.191	0.245	0.252	-0.021	103.8	10.1	7.3	164.4	107.8	148.5	63.4
	(0.044)	(0.040)	(0.040)	(0.017)	(25.6)	(2.2)	(2.5)	(32.9)	(21.6)	(30.7)	(20.6)
	[0.000]	[0.000]	[0.000]	[0.207]	[0.000]	[0.000]	[0.004]	[0.000]	[0.000]	[0.000]	[0.002]
Estimate with actual boundary	0.151	0.237	0.221	-0.061	95.3	9.5	5.3	154.3	106.7	140.9	52.7
Engineering drawing SFE (Spatial FE, Specification 2)											
SP CA	0.161	0.235	0.240	-0.051	105.6	10.8	6.7	163.2	126.4	148.6	67.6
	(0.061)	(0.055)	(0.055)	(0.035)	(34.5)	(3.7)	(4.5)	(46.9)	(33.4)	(41.4)	(31.0)
	[0.009]	[0.000]	[0.000]	[0.143]	[0.002]	[0.004]	[0.137]	[0.001]	[0.000]	[0.000]	[0.029]
Estimate with actual boundary	0.165	0.251	0.248	-0.075	147.7	10.7	7.3	145.9	115.0	130.8	19.6
# of observations	1,419	1,419	1,418	1,418	1,413	1,416	1,416	1,357	1,416	1,357	1,355
# of clusters	90	90	90	90	90	90	90	90	90	90	90
Control mean	0.317	0.155	0.163	0.074	118.0	9.3	16.5	173.0	110.8	147.4	58.8

Supplementary Appendix F Impacts of access to irrigation on rainy season largest other plot production decisions

In Section 5, we estimate the impacts of access to irrigation on sample plots on production decisions on largest other plots; as the dry season is the primary season for irrigation use, we focus this analysis on the dry seasons (2016 Dry, 2017 Dry, and 2018 Dry). We present impacts of access to irrigation on sample plots on production decisions on largest other plots during the rainy seasons in Tables S4, S5, and S6, analogous to our dry season analysis in Tables 7, 8, and 9, respectively.

We find no robustly significant impacts on rainy season production decisions on largest other plots, with the exception of increases in banana cultivation and any cultivation. We interpret the lack of impacts on other outcomes as consistent with the lack of direct effects of access to irrigation on sample plots on rainy season production, labor demand, or input demand. However, increases in banana cultivation and any cultivation are explained by the longer production cycle of bananas (which we discuss in Appendix D). As we note in Supplementary Appendix J.1.3, our model predictions for impacts of access to irrigation on dry season production decisions are robust to any within-plot across-season spillovers caused by the longer production cycle of bananas.

Table S4: No average effects of sample plot shock on largest other plots during rainy season except increased cultivation of bananas

	LOP, Rainy seasons, Discontinuity sample						
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
RDD (Site-by-season FE, Specification 3)							
SP CA	0.093	-0.005	-0.007	0.111	-0.3	-3.5	0.5
	(0.027)	(0.011)	(0.019)	(0.035)	(17.5)	(3.0)	(4.4)
	[0.001]	[0.639]	[0.723]	[0.002]	[0.988]	[0.245]	[0.902]
Sample plot effect	-0.085	0.038	0.025	-0.164	15.5	2.0	3.5
SFE (Spatial FE, Specification 4)							
SP CA	0.083	-0.004	-0.004	0.105	6.6	-2.3	4.6
	(0.028)	(0.015)	(0.022)	(0.039)	(19.5)	(3.7)	(5.0)
	[0.003]	[0.800]	[0.868]	[0.007]	[0.733]	[0.527]	[0.360]
Sample plot effect	-0.052	0.062	0.053	-0.170	10.4	2.2	3.1
# of observations	3,526	3,526	3,526	3,526	3,505	3,510	3,510
# of clusters	165	165	165	165	165	165	165
Control mean	0.858	0.027	0.070	0.228	209.3	16.3	18.6

Table S5: No heterogeneous effects of sample plot shock on largest other plots during rainy season with respect to location of largest other plots

	LOP, Rainy seasons, Discontinuity sample						
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
RDD (Site-by-season FE, Specification 3)							
SP CA	0.096	-0.000	-0.000	0.110	-2.1	-0.4	-3.4
	(0.031)	(0.010)	(0.016)	(0.045)	(22.7)	(3.3)	(5.0)
	[0.002]	[0.986]	[0.988]	[0.015]	[0.927]	[0.903]	[0.502]
SP CA * LOP CA	-0.006	-0.012	-0.016	0.002	4.3	-7.4	9.3
	(0.033)	(0.015)	(0.026)	(0.047)	(27.7)	(3.8)	(5.6)
	[0.866]	[0.447]	[0.549]	[0.969]	[0.876]	[0.048]	[0.100]
Joint F-stat [p]	6.1	0.3	0.2	5.5	0.0	2.4	1.4
	[0.003]	[0.739]	[0.835]	[0.005]	[0.988]	[0.095]	[0.258]
Sample plot effect	-0.085	0.038	0.025	-0.164	15.5	2.0	3.5
Average effect	0.093	-0.005	-0.007	0.111	-0.3	-3.5	0.5
SFE (Spatial FE, Specification 4)							
SP CA	0.074	-0.001	0.007	0.111	-6.7	-0.3	-1.4
	(0.030)	(0.012)	(0.021)	(0.049)	(24.9)	(4.0)	(5.7)
	[0.013]	[0.918]	[0.756]	[0.022]	[0.789]	[0.937]	[0.806]
SP CA * LOP CA	0.020	-0.006	-0.023	-0.013	29.4	-4.4	13.2
	(0.035)	(0.016)	(0.028)	(0.053)	(30.2)	(4.6)	(7.6)
	[0.574]	[0.737]	[0.423]	[0.813]	[0.331]	[0.334]	[0.081]
Joint F-stat [p]	4.4	0.1	0.3	3.7	0.6	0.6	1.8
	[0.012]	[0.943]	[0.720]	[0.024]	[0.568]	[0.549]	[0.163]
Sample plot effect	-0.052	0.062	0.053	-0.170	10.4	2.2	3.1
Average effect	0.083	-0.004	-0.004	0.105	6.6	-2.3	4.6
# of observations	3,526	3,526	3,526	3,526	3,505	3,510	3,510
# of clusters	165	165	165	165	165	165	165
Control mean	0.858	0.027	0.070	0.228	209.3	16.3	18.6

Table S6: No heterogeneous effects of sample plot shock on largest other plots during rainy season with respect to household characteristics

	LOP, Rainy seasons, Discontinuity sample						
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
RDD (Site-by-season FE, Specification 5)							
SP CA	0.067	-0.011	-0.024	0.096	-41.2	-9.1	-5.0
	(0.045)	(0.023)	(0.039)	(0.072)	(34.8)	(4.9)	(8.9)
	[0.136]	[0.649]	[0.545]	[0.183]	[0.236]	[0.067]	[0.578]
SP CA * # of HH members	0.005	0.001	0.003	0.003	8.2	1.1	1.0
	(0.008)	(0.004)	(0.006)	(0.012)	(5.6)	(0.9)	(1.3)
	[0.530]	[0.757]	[0.580]	[0.830]	[0.146]	[0.195]	[0.435]
SP CA * Asset index	-0.003	0.000	-0.002	0.010	12.8	-2.5	1.7
	(0.018)	(0.007)	(0.012)	(0.026)	(13.9)	(1.9)	(3.0)
	[0.849]	[0.979]	[0.893]	[0.694]	[0.358]	[0.186]	[0.562]
Joint F-stat [p]	4.4	0.1	0.1	3.3	2.0	1.5	0.4
	[0.006]	[0.969]	[0.946]	[0.021]	[0.115]	[0.222]	[0.735]
Average effect	0.093	-0.005	-0.007	0.111	-0.3	-3.5	0.5
SFE (Spatial FE, Specification 5)							
SP CA	0.055	-0.013	-0.037	0.027	-10.5	-11.1	0.6
	(0.052)	(0.027)	(0.046)	(0.092)	(40.3)	(5.7)	(10.2)
	[0.292]	[0.626]	[0.418]	[0.767]	[0.794]	[0.052]	[0.956]
SP CA * # of HH members	0.005	0.002	0.007	0.015	3.3	1.8	0.8
	(0.011)	(0.004)	(0.008)	(0.017)	(6.4)	(1.1)	(1.7)
	[0.657]	[0.650]	[0.392]	[0.372]	[0.604]	[0.103]	[0.654]
SP CA * Asset index	-0.005	-0.004	-0.005	0.012	22.9	-1.9	0.1
	(0.018)	(0.008)	(0.014)	(0.027)	(14.0)	(2.1)	(3.2)
	[0.799]	[0.661]	[0.703]	[0.642]	[0.101]	[0.346]	[0.982]
Joint F-stat [p]	3.0	0.1	0.3	3.1	1.6	1.3	0.4
	[0.029]	[0.958]	[0.860]	[0.026]	[0.190]	[0.271]	[0.756]
Average effect	0.083	-0.004	-0.004	0.105	6.6	-2.3	4.6
# of observations	3,521	3,521	3,521	3,521	3,500	3,505	3,505
# of clusters	165	165	165	165	165	165	165
Control mean	0.858	0.027	0.070	0.228	209.3	16.3	18.6

Supplementary Appendix G Additional robustness

To complement the analysis in Section 3, we estimate the impacts of access to irrigation using specifications similar to specifications 1 and 2, but with additional controls or using alternative weights. We present these estimates similarly to Table 4, and compare estimated coefficients to those in Table 4.

Reweighting by inverse number of plots First, as described in Section 2.2.1, our sampling strategy oversamples households who managed relatively more plots at baseline, and these households are therefore likely to be overrepresented in our analysis relative to their share of the population. To test the robustness of our main results to changes in sampling, we estimate Specifications 1, 2, 3, and 4 reweighting by the inverse number of plots, and we present these estimates in Tables S7 and S8. The patterns in the results we describe in Sections 3 and 5 are robust to this alternative weighting.

Table S7: Estimated effects of access to irrigation are robust to reweighting by the inverse of # of plots

(a) Dry season

	SP, Dry season, Discontinuity sample										
	Cultivated	Irrigated	Horticulture	Banana	HH labor/ha	Input exp./ha	Hired labor exp./ha	Yield	Sales /ha	Profits/ha Shadow wage = 0	Profits/ha Shadow wage = 800
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
RDD (Site-by-season FE, Specification 1), Weighted											
SP CA	-0.000	0.163	0.139	-0.130	61.7	6.0	3.1	58.7	42.9	49.7	1.8
	(0.046)	(0.026)	(0.024)	(0.046)	(16.5)	(1.7)	(1.8)	(20.7)	(14.6)	(18.2)	(14.5)
	[0.999]	[0.000]	[0.000]	[0.004]	[0.000]	[0.001]	[0.087]	[0.005]	[0.003]	[0.006]	[0.902]
# of observations	2,439	2,439	2,438	2,438	2,428	2,431	2,431	2,307	2,431	2,307	2,305
# of clusters	173	173	173	173	173	173	173	173	173	173	173
Unweighted estimate	0.004	0.163	0.137	-0.138	71.6	6.1	3.2	64.8	50.2	56.3	2.2

(b) Rainy seasons

	SP, Rainy seasons, Discontinuity sample										
	Cultivated	Irrigated	Horticulture	Banana	HH labor/ha	Input exp./ha	Hired labor exp./ha	Yield	Sales /ha	Profits/ha Shadow wage = 0	Profits/ha Shadow wage = 800
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
RDD (Site-by-season FE, Specification 1), Weighted											
SP CA	-0.085	0.041	0.014	-0.159	15.7	3.6	5.7	-3.0	-3.4	-11.6	-23.0
	(0.027)	(0.010)	(0.020)	(0.050)	(24.3)	(2.8)	(4.4)	(29.3)	(17.7)	(26.0)	(22.8)
	[0.002]	[0.000]	[0.483]	[0.002]	[0.520]	[0.205]	[0.190]	[0.917]	[0.850]	[0.657]	[0.313]
# of observations	4,071	4,071	4,070	4,070	4,053	4,060	4,060	3,922	4,060	3,922	3,915
# of clusters	173	173	173	173	173	173	173	173	173	173	173
Unweighted estimate	-0.085	0.038	0.025	-0.164	15.5	2.0	3.5	-18.4	-10.7	-22.7	-33.4

Controls for distance to command area boundary Second, as described in Sections 3.1 and 5.1, our primary Specifications 1, 2, 3, and 4 control for distance to the command area boundary and its interaction with the command area indicator. As an alternative, we consider the robustness of these specifications to the functional form on the control for distance to the command area boundary. First, we estimate Specifications 1, 2, 3, and 4 omitting controls for distances to the command area boundary and its interaction with the command area indicator (along with log area,

Table S8: Estimated substitution effects are robust to reweighting by the inverse of # of plots

	LOP, Dry season, Discontinuity sample						
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
RDD (Site-by-season FE, Specification 3), Weighted							
SP CA	0.030	-0.036	-0.027	0.087	-27.0	-3.4	0.0
	(0.043)	(0.023)	(0.019)	(0.041)	(17.4)	(2.1)	(1.8)
	[0.483]	[0.111]	[0.171]	[0.037]	[0.120]	[0.098]	[0.993]
# of observations	2,107	2,107	2,107	2,107	2,094	2,097	2,097
# of clusters	165	165	165	165	165	165	165
Unweighted estimate	0.028	-0.049	-0.044	0.086	-36.4	-5.8	-1.9

and for Specifications 3 and 4, log largest other plot area and the largest other plot command area indicator), and present these estimates in Tables S9 and S10. Second, we estimate Specifications 1, 2, 3, and 4 with additional controls for distance to the command area boundary squared and its interaction with the command area indicator, and we present these estimates in Tables S11 and S12. In both cases, the patterns in the results we describe in Sections 3 and 5 are robust to the choice of functional form on controls for distance to the command area boundary.

Table S9: Estimated effects of access to irrigation are robust to omission of key controls

(a) Dry season

	SP, Dry season, Discontinuity sample										
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha	Yield	Sales /ha	Profits/ha Shadow wage = 0	Profits/ha Shadow wage = 800
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
RDD (Site-by-season FE, Specification 1), No controls											
SP CA	0.032	0.196	0.174	-0.134	66.0	6.5	3.5	44.8	41.1	36.2	-9.8
	(0.032)	(0.019)	(0.020)	(0.024)	(15.3)	(1.2)	(1.5)	(20.0)	(12.8)	(18.3)	(11.9)
	[0.318]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.018]	[0.025]	[0.001]	[0.048]	[0.409]
# of observations	2,439	2,439	2,438	2,438	2,428	2,431	2,431	2,307	2,431	2,307	2,305
# of clusters	173	173	173	173	173	173	173	173	173	173	173
RDD estimate	0.004	0.163	0.137	-0.138	71.6	6.1	3.2	64.8	50.2	56.3	2.2
SFE estimate	0.028	0.177	0.158	-0.144	79.2	4.6	2.5	48.1	42.8	42.4	-8.5
Control mean	0.383	0.051	0.058	0.244	60.1	2.4	3.1	80.5	47.3	75.2	31.6

(b) Rainy seasons

	SP, Rainy seasons, Discontinuity sample										
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha	Yield	Sales /ha	Profits/ha Shadow wage = 0	Profits/ha Shadow wage = 800
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
RDD (Site-by-season FE, Specification 1), No controls											
SP CA	-0.048	0.045	0.049	-0.150	-5.7	3.2	5.6	-45.1	-6.1	-52.3	-47.6
	(0.020)	(0.007)	(0.011)	(0.025)	(19.5)	(2.0)	(2.4)	(22.7)	(11.0)	(21.1)	(17.0)
	[0.015]	[0.000]	[0.000]	[0.000]	[0.771]	[0.109]	[0.021]	[0.047]	[0.579]	[0.013]	[0.005]
# of observations	4,071	4,071	4,070	4,070	4,053	4,060	4,060	3,922	4,060	3,922	3,915
# of clusters	173	173	173	173	173	173	173	173	173	173	173
RDD estimate	-0.085	0.038	0.025	-0.164	15.5	2.0	3.5	-18.4	-10.7	-22.7	-33.4
SFE estimate	-0.052	0.062	0.053	-0.170	10.4	2.2	3.1	-19.2	5.8	-23.2	-31.3
Control mean	0.836	0.016	0.071	0.274	230.0	16.2	15.6	273.5	87.1	242.0	59.0

Table S10: Estimated substitution effects are robust to omission of key controls

	LOP, Dry season, Discontinuity sample						
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
RDD (Site-by-season FE, Specification 3), No controls							
SP CA	0.037	-0.023	-0.020	0.057	-17.6	-1.9	-1.2
	(0.023)	(0.016)	(0.016)	(0.023)	(12.1)	(1.5)	(1.2)
	[0.112]	[0.156]	[0.220]	[0.014]	[0.144]	[0.181]	[0.307]
# of observations	2,107	2,107	2,107	2,107	2,094	2,097	2,097
# of clusters	165	165	165	165	165	165	165
RDD estimate	0.028	-0.049	-0.044	0.086	-36.4	-5.8	-1.9
SFE estimate	0.002	-0.041	-0.042	0.067	-36.2	-6.6	-0.1

Table S11: Estimated effects of access to irrigation are robust to controlling for distance to the command area boundary squared and its interaction with the command area indicator

(a) Dry season

	SP, Dry season, Discontinuity sample										
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha	Yield	Sales /ha	Profits/ha Shadow wage = 0	= 800
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
RDD (Site-by-season FE, Specification 1), Quadratic RV											
SP CA	0.019	0.129	0.123	-0.128	62.9	6.7	6.1	36.4	30.8	23.8	-22.4
	(0.057)	(0.029)	(0.028)	(0.056)	(22.7)	(2.0)	(2.2)	(34.7)	(25.1)	(33.2)	(28.2)
	[0.743]	[0.000]	[0.000]	[0.022]	[0.006]	[0.001]	[0.007]	[0.295]	[0.219]	[0.473]	[0.428]
Effect w/o quadratic RV	0.004	0.163	0.137	-0.138	71.6	6.1	3.2	64.8	50.2	56.3	2.2
SFE (Spatial FE, Specification 2), Quadratic RV											
SP CA	0.089	0.130	0.132	-0.055	67.7	5.7	6.4	56.2	36.8	44.0	-1.6
	(0.054)	(0.035)	(0.035)	(0.052)	(21.6)	(2.5)	(2.9)	(34.7)	(23.2)	(32.2)	(27.9)
	[0.097]	[0.000]	[0.000]	[0.286]	[0.002]	[0.024]	[0.024]	[0.105]	[0.113]	[0.173]	[0.955]
Effect w/o quadratic RV	0.028	0.177	0.158	-0.144	79.2	4.6	2.5	48.1	42.8	42.4	-8.5
# of observations	2,439	2,439	2,438	2,438	2,428	2,431	2,431	2,307	2,431	2,307	2,305
# of clusters	173	173	173	173	173	173	173	173	173	173	173

(b) Rainy seasons

	SP, Rainy seasons, Discontinuity sample										
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha	Yield	Sales /ha	Profits/ha Shadow wage = 0	= 800
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
RDD (Site-by-season FE, Specification 1), Quadratic RV											
SP CA	-0.057	0.036	0.001	-0.140	16.2	2.8	3.6	-21.9	-43.0	-27.1	-39.1
	(0.033)	(0.014)	(0.031)	(0.057)	(26.8)	(4.0)	(4.5)	(49.9)	(31.8)	(46.6)	(47.3)
	[0.087]	[0.008]	[0.962]	[0.015]	[0.546]	[0.480]	[0.417]	[0.662]	[0.176]	[0.561]	[0.409]
Effect w/o quadratic RV	-0.085	0.038	0.025	-0.164	15.5	2.0	3.5	-18.4	-10.7	-22.7	-33.4
SFE (Spatial FE, Specification 2), Quadratic RV											
SP CA	-0.019	0.053	0.015	-0.077	2.3	-0.2	-0.2	-46.2	-35.0	-45.3	-49.6
	(0.038)	(0.016)	(0.037)	(0.050)	(31.5)	(3.8)	(4.8)	(39.2)	(26.2)	(37.2)	(39.3)
	[0.622]	[0.001]	[0.694]	[0.122]	[0.941]	[0.956]	[0.961]	[0.238]	[0.182]	[0.223]	[0.207]
Effect w/o quadratic RV	-0.052	0.062	0.053	-0.170	10.4	2.2	3.1	-19.2	5.8	-23.2	-31.3
# of observations	4,071	4,071	4,070	4,070	4,053	4,060	4,060	3,922	4,060	3,922	3,915
# of clusters	173	173	173	173	173	173	173	173	173	173	173

Table S12: Estimated substitution effects are robust to controlling for distance to the command area boundary squared and its interaction with the command area indicator

	LOP, Dry season, Discontinuity sample						
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
RDD (Site-by-season FE, Specification 3), Quadratic RV							
SP CA	0.106	-0.031	-0.036	0.140	-40.8	-7.0	-2.1
	(0.055)	(0.036)	(0.035)	(0.046)	(32.5)	(3.9)	(3.0)
	[0.057]	[0.387]	[0.309]	[0.002]	[0.210]	[0.074]	[0.495]
Effect w/o quadratic RV	0.028	-0.049	-0.044	0.086	-36.4	-5.8	-1.9
SFE (Spatial FE, Specification 4), Quadratic RV							
SP CA	0.097	-0.001	-0.017	0.151	-43.3	-7.9	-0.8
	(0.053)	(0.041)	(0.039)	(0.043)	(33.7)	(3.9)	(3.5)
	[0.068]	[0.979]	[0.662]	[0.000]	[0.199]	[0.040]	[0.812]
Effect w/o quadratic RV	0.002	-0.041	-0.042	0.067	-36.2	-6.6	-0.1
# of observations	2,107	2,107	2,107	2,107	2,094	2,097	2,097
# of clusters	165	165	165	165	165	165	165
Control mean	0.368	0.114	0.107	0.201	68.1	5.4	3.7

Non-cultivable land Third, as described in Sections 3.1 and 5.1, we demonstrate the robustness of our results to spatial fixed effects specifications in part to ensure comparisons are only made over proximate plots, to control for spatially correlated unobservables such as heterogeneity in productivity caused by soil characteristics. As a complement, we also estimate Specifications 1, 2, 3, and 4 restricting to sample plots that are at least 50m from the nearest non-cultivable sample point. We present these estimates in Tables S13 and S14. The patterns in the results we describe in Sections 3 and 5 are robust to this sample restriction.

Table S13: Estimated effects of access to irrigation are robust to restricting to sample plots without nearby non-cultivable land

(a) Dry season

	SP, Dry season, Discontinuity sample, Drop SP near non-cultivable land										
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha	Yield	Sales /ha	Profits/ha Shadow wage = 0	= 800
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
RDD (Site-by-season FE, Specification 1)											
SP CA	-0.023	0.148	0.116	-0.143	69.6	7.2	5.7	64.5	53.0	51.8	0.7
	(0.056)	(0.036)	(0.035)	(0.051)	(26.6)	(2.4)	(2.8)	(33.9)	(22.4)	(30.7)	(24.9)
	[0.687]	[0.000]	[0.001]	[0.006]	[0.009]	[0.003]	[0.046]	[0.057]	[0.018]	[0.091]	[0.978]
Effect w/ SP near non-cultivable land	0.004	0.163	0.137	-0.138	71.6	6.1	3.2	64.8	50.2	56.3	2.2
SFE (Spatial FE, Specification 2)											
SP CA	-0.058	0.110	0.103	-0.182	61.5	4.1	2.5	32.1	20.9	24.7	-21.9
	(0.055)	(0.037)	(0.037)	(0.049)	(29.8)	(2.6)	(2.7)	(36.2)	(22.5)	(33.4)	(26.9)
	[0.287]	[0.003]	[0.005]	[0.000]	[0.039]	[0.121]	[0.346]	[0.374]	[0.353]	[0.459]	[0.415]
Effect w/ SP near non-cultivable land	0.028	0.177	0.158	-0.144	79.2	4.6	2.5	48.1	42.8	42.4	-8.5
# of observations	1,265	1,265	1,265	1,265	1,257	1,259	1,259	1,191	1,259	1,191	1,190
# of clusters	128	128	128	128	128	128	128	128	128	128	128

(b) Rainy seasons

	SP, Rainy seasons, Discontinuity sample, Drop SP near non-cultivable land										
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha	Yield	Sales /ha	Profits/ha Shadow wage = 0	= 800
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
RDD (Site-by-season FE, Specification 1)											
SP CA	-0.082	0.030	-0.001	-0.161	11.9	4.6	3.0	-36.4	-29.9	-45.3	-54.6
	(0.036)	(0.014)	(0.024)	(0.053)	(30.8)	(4.5)	(5.5)	(46.9)	(30.7)	(43.6)	(42.2)
	[0.024]	[0.034]	[0.973]	[0.003]	[0.700]	[0.305]	[0.580]	[0.438]	[0.332]	[0.298]	[0.196]
Effect w/ SP near non-cultivable land	-0.085	0.038	0.025	-0.164	15.5	2.0	3.5	-18.4	-10.7	-22.7	-33.4
SFE (Spatial FE, Specification 2)											
SP CA	-0.087	0.039	0.000	-0.190	4.2	3.1	2.3	-61.5	-35.5	-68.0	-70.9
	(0.041)	(0.018)	(0.028)	(0.054)	(39.8)	(5.8)	(6.9)	(50.4)	(38.5)	(44.2)	(43.1)
	[0.033]	[0.035]	[0.993]	[0.000]	[0.915]	[0.595]	[0.738]	[0.223]	[0.357]	[0.124]	[0.100]
Effect w/ SP near non-cultivable land	-0.052	0.062	0.053	-0.170	10.4	2.2	3.1	-19.2	5.8	-23.2	-31.3
# of observations	2,111	2,111	2,110	2,110	2,103	2,106	2,106	2,036	2,106	2,036	2,033
# of clusters	128	128	128	128	128	128	128	128	128	128	128

Table S14: Estimated substitution effects are robust to restricting to sample plots without nearby non-cultivable land

	LOP, Dry season, Discontinuity sample, Drop SP near non-cultivable land						
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
RDD (Site-by-season FE, Specification 3)							
SP CA	0.070	-0.027	-0.019	0.102	-42.9	-3.8	0.4
	(0.056)	(0.031)	(0.028)	(0.050)	(29.2)	(2.8)	(1.7)
	[0.212]	[0.377]	[0.492]	[0.042]	[0.142]	[0.176]	[0.802]
Effect w/ SP near non-cultivable land	0.028	-0.049	-0.044	0.086	-36.4	-5.8	-1.9
SFE (Spatial FE, Specification 4)							
SP CA	0.029	-0.041	-0.031	0.076	-49.1	-4.1	0.6
	(0.060)	(0.037)	(0.031)	(0.054)	(29.9)	(3.1)	(1.7)
	[0.623]	[0.274]	[0.317]	[0.159]	[0.101]	[0.181]	[0.704]
Effect w/ SP near non-cultivable land	0.002	-0.041	-0.042	0.067	-36.2	-6.6	-0.1
# of observations	1,106	1,106	1,106	1,106	1,099	1,102	1,102
# of clusters	122	122	122	122	122	122	122
Control mean	0.374	0.099	0.089	0.224	68.9	3.9	1.9

Clustering standard errors Fourth, as described in Section 3.1, we estimate Specifications 1 and 3 with standard errors clustered at the water user group level. As an alternative, we estimate this specification with standard errors clustered at the zone level instead of the water user group level, and we present these estimates in Tables S15 and S16; we describe differences between zones and water user groups in Section 2.1. The patterns of statistical significance we describe in Sections 3 and 5 are unaffected by instead clustering at the zone level.

Table S15: Patterns of statistical significance of the effects of access to irrigation are robust to alternative clustering

(a) Dry season

	SP, Dry season, Discontinuity sample										
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ha	Input exp./ha	Hired labor exp./ha	Yield	Sales /ha	Profits/ha Shadow wage = 0	Profits/ha Shadow wage = 800
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
RDD (Site-by-season FE, Specification 1), Zone cluster											
SP CA	0.004	0.163	0.137	-0.138	71.6	6.1	3.2	64.8	50.2	56.3	2.2
	(0.052)	(0.039)	(0.033)	(0.041)	(25.2)	(1.7)	(2.8)	(38.4)	(22.8)	(34.8)	(21.4)
	[0.936]	[0.000]	[0.000]	[0.001]	[0.005]	[0.000]	[0.267]	[0.092]	[0.028]	[0.106]	[0.918]
# of observations	2,439	2,439	2,438	2,438	2,428	2,431	2,431	2,307	2,431	2,307	2,305
# of clusters	22	22	22	22	22	22	22	22	22	22	22
SE w/ WUG cluster	(0.041)	(0.024)	(0.024)	(0.037)	(18.2)	(1.5)	(1.9)	(23.0)	(14.3)	(20.9)	(16.5)
p w/ WUG cluster	[0.917]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.100]	[0.005]	[0.000]	[0.007]	[0.893]

(b) Rainy seasons

	SP, Rainy seasons, Discontinuity sample										
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ha	Input exp./ha	Hired labor exp./ha	Yield	Sales /ha	Profits/ha Shadow wage = 0	Profits/ha Shadow wage = 800
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
RDD (Site-by-season FE, Specification 1), Zone cluster											
SP CA	-0.085	0.038	0.025	-0.164	15.5	2.0	3.5	-18.4	-10.7	-22.7	-33.4
	(0.025)	(0.012)	(0.018)	(0.051)	(18.2)	(2.5)	(3.8)	(29.8)	(19.6)	(26.3)	(32.1)
	[0.001]	[0.001]	[0.168]	[0.001]	[0.396]	[0.427]	[0.355]	[0.537]	[0.585]	[0.388]	[0.298]
# of observations	4,071	4,071	4,070	4,070	4,053	4,060	4,060	3,922	4,060	3,922	3,915
# of clusters	22	22	22	22	22	22	22	22	22	22	22
SE w/ WUG cluster	(0.026)	(0.009)	(0.018)	(0.038)	(24.0)	(3.0)	(3.5)	(30.7)	(18.5)	(28.4)	(26.7)
p w/ WUG cluster	[0.001]	[0.000]	[0.168]	[0.000]	[0.520]	[0.503]	[0.313]	[0.550]	[0.563]	[0.425]	[0.211]

Table S16: Patterns of statistical significance of substitution effects are robust to alternative clustering

	LOP, Dry season, Discontinuity sample						
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ha	Input exp./ha	Hired labor exp./ha
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
RDD (Site-by-season FE, Specification 3), Zone cluster							
SP CA	0.028	-0.049	-0.044	0.086	-36.4	-5.8	-1.9
	(0.042)	(0.032)	(0.028)	(0.030)	(22.2)	(2.5)	(1.9)
	[0.499]	[0.122]	[0.112]	[0.004]	[0.102]	[0.020]	[0.304]
# of observations	2,107	2,107	2,107	2,107	2,094	2,097	2,097
# of clusters	22	22	22	22	22	22	22
SE w/ WUG cluster	(0.040)	(0.026)	(0.023)	(0.032)	(20.6)	(2.7)	(2.1)
p w/ WUG cluster	[0.486]	[0.055]	[0.058]	[0.007]	[0.078]	[0.032]	[0.365]

Controls for household characteristics Fifth, as described in Section 3.1.1, the coefficients on household head completed primary and number of household members (15-64) in the balance test in Table 3 may appear economically significant, although only the coefficient on household head completed primary is statistically significant and only in some specifications. To test the robustness of our results, we therefore estimate Specifications 1, 2, 3, and 4 with household head completed primary and number of household members (15-64) included as controls, and we present these estimates in Tables S17 and S18. The patterns in the results we describe in Sections 3 and 5 are robust to the inclusion of these controls.

Table S17: Estimated effects of access to irrigation are robust to controlling for household head completed primary and number of household members (15-64)

(a) Dry season

	SP, Dry season, Discontinuity sample										
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ha	Input exp./ha	Hired labor exp./ha	Yield	Sales /ha	Profits/ha Shadow wage = 0	Profits/ha Shadow wage = 800
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
RDD (Site-by-season FE, Specification 1), HH controls											
SP CA	0.002	0.160	0.136	-0.137	69.1	5.8	3.1	64.5	49.3	55.9	2.7
	(0.041)	(0.024)	(0.024)	(0.036)	(18.9)	(1.5)	(2.0)	(23.7)	(14.6)	(21.6)	(17.0)
	[0.954]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.125]	[0.007]	[0.001]	[0.010]	[0.873]
Effect w/o HH controls	0.004	0.163	0.137	-0.138	71.6	6.1	3.2	64.8	50.2	56.3	2.2
SFE (Spatial FE, Specification 2), HH controls											
SP CA	0.025	0.172	0.155	-0.142	76.9	4.3	2.6	48.5	42.3	42.7	-7.2
	(0.043)	(0.031)	(0.029)	(0.034)	(22.5)	(1.9)	(2.4)	(27.0)	(17.5)	(24.5)	(20.2)
	[0.571]	[0.000]	[0.000]	[0.000]	[0.001]	[0.026]	[0.290]	[0.073]	[0.015]	[0.081]	[0.722]
Effect w/o HH controls	0.028	0.177	0.158	-0.144	79.2	4.6	2.5	48.1	42.8	42.4	-8.5
# of observations	2,431	2,431	2,430	2,430	2,420	2,423	2,423	2,300	2,423	2,300	2,298
# of clusters	171	171	171	171	171	171	171	171	171	171	171

(b) Rainy seasons

	SP, Rainy seasons, Discontinuity sample										
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ha	Input exp./ha	Hired labor exp./ha	Yield	Sales /ha	Profits/ha Shadow wage = 0	Profits/ha Shadow wage = 800
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
RDD (Site-by-season FE, Specification 1), HH controls											
SP CA	-0.084	0.035	0.020	-0.161	11.3	1.4	2.9	-25.3	-13.7	-28.9	-36.0
	(0.026)	(0.009)	(0.017)	(0.038)	(24.5)	(3.0)	(3.5)	(31.3)	(18.5)	(28.9)	(26.9)
	[0.001]	[0.000]	[0.252]	[0.000]	[0.643]	[0.632]	[0.401]	[0.419]	[0.461]	[0.318]	[0.181]
Effect w/o HH controls	-0.085	0.038	0.025	-0.164	15.5	2.0	3.5	-18.4	-10.7	-22.7	-33.4
SFE (Spatial FE, Specification 2), HH controls											
SP CA	-0.055	0.059	0.048	-0.168	6.5	1.6	2.5	-23.2	3.0	-26.3	-31.3
	(0.027)	(0.012)	(0.025)	(0.033)	(26.3)	(3.0)	(4.5)	(30.6)	(21.4)	(27.7)	(32.4)
	[0.042]	[0.000]	[0.051]	[0.000]	[0.805]	[0.597]	[0.581]	[0.450]	[0.888]	[0.342]	[0.334]
Effect w/o HH controls	-0.052	0.062	0.053	-0.170	10.4	2.2	3.1	-19.2	5.8	-23.2	-31.3
# of observations	4,058	4,058	4,057	4,057	4,040	4,047	4,047	3,910	4,047	3,910	3,903
# of clusters	171	171	171	171	171	171	171	171	171	171	171

Table S18: Estimated substitution effects are robust to controlling for household head completed primary and number of household members (15-64)

	LOP, Dry season, Discontinuity sample						
	Cultivated	Irrigated	Horticulture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
RDD (Site-by-season FE, Specification 3), HH controls							
SP CA	0.025	-0.052	-0.048	0.086	-40.3	-6.2	-2.4
	(0.041)	(0.026)	(0.024)	(0.032)	(20.7)	(2.8)	(2.1)
	[0.535]	[0.044]	[0.042]	[0.007]	[0.051]	[0.024]	[0.268]
Effect w/o HH controls	0.028	-0.049	-0.044	0.086	-36.4	-5.8	-1.9
SFE (Spatial FE, Specification 4), HH controls							
SP CA	-0.002	-0.042	-0.044	0.065	-38.3	-6.8	-0.5
	(0.048)	(0.033)	(0.029)	(0.037)	(24.3)	(2.8)	(2.2)
	[0.968]	[0.200]	[0.131]	[0.077]	[0.115]	[0.014]	[0.831]
Effect w/o HH controls	0.002	-0.041	-0.042	0.067	-36.2	-6.6	-0.1
# of observations	2,098	2,098	2,098	2,098	2,085	2,088	2,088
# of clusters	163	163	163	163	163	163	163
Control mean	0.368	0.114	0.108	0.200	68.0	5.4	3.7

Controls for elevation Sixth, as described in Section Appendix D, command area plots are significantly lower in elevation than plots outside the command area, although this difference is much smaller when we use a spatial fixed effects specification. To test the robustness of our main results, we therefore estimate Specifications 1, 2, 3, and 4 with elevation included as a control, and we present these estimates in Tables S19 and S20. The patterns in the results we describe in Sections 3 and 5 are robust to the inclusion of elevation as a control.

Table S19: Estimated effects of access to irrigation are robust to controlling for elevation

(a) Dry season

	SP, Dry season, Discontinuity sample										
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha	Yield	Sales /ha	Profits/ha Shadow wage = 0	= 800
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
RDD (Site-by-season FE, Specification 1), Elevation control											
SP CA	0.001	0.174	0.148	-0.146	73.0	6.3	2.6	62.0	49.7	54.0	-0.2
	(0.041)	(0.025)	(0.024)	(0.037)	(19.1)	(1.6)	(2.0)	(24.4)	(15.8)	(22.3)	(17.6)
	[0.975]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.195]	[0.011]	[0.002]	[0.015]	[0.991]
Effect w/o elevation control	0.004	0.163	0.137	-0.138	71.6	6.1	3.2	64.8	50.2	56.3	2.2
SFE (Spatial FE, Specification 2), Elevation control											
SP CA	0.030	0.161	0.150	-0.119	73.2	3.1	1.4	39.4	39.4	36.3	-7.7
	(0.044)	(0.031)	(0.030)	(0.035)	(24.1)	(1.9)	(2.2)	(27.5)	(18.5)	(25.2)	(22.1)
	[0.496]	[0.000]	[0.000]	[0.001]	[0.002]	[0.106]	[0.523]	[0.153]	[0.033]	[0.149]	[0.729]
Effect w/o elevation control	0.028	0.177	0.158	-0.144	79.2	4.6	2.5	48.1	42.8	42.4	-8.5
# of observations	2,439	2,439	2,438	2,438	2,428	2,431	2,431	2,307	2,431	2,307	2,305
# of clusters	173	173	173	173	173	173	173	173	173	173	173

(b) Rainy seasons

	SP, Rainy seasons, Discontinuity sample										
	Culti-vated	Irri-gated	Horti-culture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha	Yield	Sales /ha	Profits/ha Shadow wage = 0	= 800
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
RDD (Site-by-season FE, Specification 1), Elevation control											
SP CA	-0.073	0.039	0.034	-0.173	19.0	2.8	4.0	-17.1	-12.4	-22.5	-35.9
	(0.026)	(0.010)	(0.018)	(0.038)	(24.2)	(3.0)	(3.7)	(32.3)	(18.9)	(30.1)	(29.1)
	[0.005]	[0.000]	[0.060]	[0.000]	[0.432]	[0.350]	[0.273]	[0.595]	[0.513]	[0.456]	[0.218]
Effect w/o elevation control	-0.085	0.038	0.025	-0.164	15.5	2.0	3.5	-18.4	-10.7	-22.7	-33.4
SFE (Spatial FE, Specification 2), Elevation control											
SP CA	-0.046	0.055	0.052	-0.143	6.1	0.9	2.1	-27.8	3.1	-29.4	-33.8
	(0.029)	(0.013)	(0.026)	(0.035)	(28.0)	(3.2)	(4.9)	(32.9)	(23.2)	(29.9)	(35.3)
	[0.113]	[0.000]	[0.045]	[0.000]	[0.827]	[0.774]	[0.665]	[0.398]	[0.894]	[0.325]	[0.339]
Effect w/o elevation control	-0.052	0.062	0.053	-0.170	10.4	2.2	3.1	-19.2	5.8	-23.2	-31.3
# of observations	4,071	4,071	4,070	4,070	4,053	4,060	4,060	3,922	4,060	3,922	3,915
# of clusters	173	173	173	173	173	173	173	173	173	173	173

Table S20: Estimated substitution effects are robust to controlling for sample plot elevation

	LOP, Dry season, Discontinuity sample						
	Cultivated	Irrigated	Horticulture	Banana	HH labor/ ha	Input exp./ha	Hired labor exp./ha
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
RDD (Site-by-season FE, Specification 3), Elevation control							
SP CA	0.016	-0.045	-0.040	0.076	-38.9	-6.3	-1.6
	(0.039)	(0.026)	(0.024)	(0.032)	(20.3)	(2.8)	(2.1)
	[0.689]	[0.086]	[0.097]	[0.017]	[0.055]	[0.025]	[0.456]
Effect w/o elevation control	0.028	-0.049	-0.044	0.086	-36.4	-5.8	-1.9
SFE (Spatial FE, Specification 4), Elevation control							
SP CA	-0.005	-0.039	-0.043	0.063	-38.7	-6.8	-0.3
	(0.048)	(0.034)	(0.030)	(0.038)	(25.0)	(3.0)	(2.4)
	[0.916]	[0.252]	[0.148]	[0.093]	[0.121]	[0.025]	[0.913]
Effect w/o elevation control	0.002	-0.041	-0.042	0.067	-36.2	-6.6	-0.1
# of observations	2,107	2,107	2,107	2,107	2,094	2,097	2,097
# of clusters	165	165	165	165	165	165	165
Control mean	0.368	0.114	0.107	0.201	68.1	5.4	3.7

Supplementary Appendix H Balance for analysis of heterogeneous impacts on largest other plots

In Section 5.1.1, we estimated the effect of sample plot access to irrigation on the sample plot affected characteristics of largest other plots, as a test of exogeneity. However, much of our analysis of the impacts of access to irrigation on the sample plot on production decisions on largest other plots involved testing for heterogeneous impacts with respect to the location of the largest other plot, household size, and household wealth. We therefore test below whether access to irrigation on the sample plot has heterogeneous impacts on characteristics of largest other plots with respect to the location of the largest other plot, household size, and household wealth, in Tables S21, S22, and S23, respectively. Overall, we confirm balance, with the exceptions of pre-construction dry season NDVI in Table S21 and renting out in Table S23 which (as 2 of 24 tests across these balance tables) are likely the produce of statistical noise.

Table S21: Balance: Largest other plot characteristics (CA heterogeneity)

	Full sample	Discontinuity sample			
	SP CA * LOP CA Coef. (SE) [p-value]	SP CA * LOP CA Coef. (SE) [p-value]			
	(1)	(2)	(3)	(4)	(5)
Dep. var. (LOP, Landsat)					
100 * NDVI (pre-2009)	0.840	0.524	0.632	0.530	0.612
	(0.293)	(0.337)	(0.343)	(0.333)	(0.342)
	[0.004]	[0.120]	[0.065]	[0.111]	[0.073]
100 * NDVI (pre-2009, Dry)	1.019	0.691	0.809	0.700	0.788
	(0.325)	(0.316)	(0.420)	(0.315)	(0.419)
	[0.002]	[0.029]	[0.054]	[0.026]	[0.060]
100 * NDVI (pre-2009, Rainy)	0.770	0.458	0.550	0.464	0.531
	(0.302)	(0.384)	(0.335)	(0.380)	(0.335)
	[0.011]	[0.233]	[0.101]	[0.222]	[0.113]
Dep. var. (LOP, Baseline)					
log GPS area	-0.242	-0.031	0.074		
	(0.136)	(0.170)	(0.217)		
	[0.076]	[0.855]	[0.732]		
Own plot	0.013	-0.016	-0.010	-0.015	-0.012
	(0.030)	(0.041)	(0.058)	(0.041)	(0.057)
	[0.658]	[0.705]	[0.864]	[0.713]	[0.838]
Owned plot >5 years	-0.010	-0.036	-0.035	-0.030	-0.034
	(0.030)	(0.030)	(0.040)	(0.030)	(0.041)
	[0.748]	[0.239]	[0.385]	[0.321]	[0.407]
Rented out, farmer	0.042	0.021	0.033	0.020	0.034
	(0.021)	(0.027)	(0.030)	(0.028)	(0.030)
	[0.050]	[0.450]	[0.270]	[0.459]	[0.255]
Slope	-0.001	0.004	0.028	0.004	0.028
	(0.018)	(0.020)	(0.027)	(0.020)	(0.027)
	[0.969]	[0.850]	[0.291]	[0.839]	[0.302]
Omnibus F-stat [p]	2.0	1.0	1.2	1.0	1.3
	[0.049]	[0.472]	[0.271]	[0.413]	[0.223]
Controls					
SP CA	X	X	X	X	X
Site FE		X		X	
SP distance to boundary		X	X	X	X
SP log GPS area				X	X
LOP log GPS area				X	X
LOP CA	X	X	X	X	X
Spatial FE			X		X

Table S22: Balance: Largest other plot characteristics (# of HH members heterogeneity)

	Full sample	Discontinuity sample			
	SP CA * # of HH members Coef. (SE) [p-value]	SP CA * # of HH members Coef. (SE) [p-value]			
	(1)	(2)	(3)	(4)	(5)
Dep. var. (LOP, Landsat)					
100 * NDVI (pre-2009)	0.090	0.112	-0.032	0.128	-0.029
	(0.079)	(0.087)	(0.098)	(0.080)	(0.094)
	[0.255]	[0.200]	[0.741]	[0.110]	[0.757]
100 * NDVI (pre-2009, Dry)	0.099	0.090	-0.021	0.102	-0.019
	(0.089)	(0.098)	(0.118)	(0.089)	(0.113)
	[0.271]	[0.361]	[0.860]	[0.251]	[0.868]
100 * NDVI (pre-2009, Rainy)	0.086	0.117	-0.042	0.136	-0.038
	(0.080)	(0.090)	(0.097)	(0.085)	(0.093)
	[0.285]	[0.197]	[0.667]	[0.109]	[0.685]
Dep. var. (LOP, Baseline)					
log GPS area	-0.033	-0.055	-0.058		
	(0.031)	(0.048)	(0.050)		
	[0.291]	[0.244]	[0.250]		
Own plot	0.008	0.012	0.015	0.012	0.016
	(0.009)	(0.010)	(0.014)	(0.010)	(0.013)
	[0.340]	[0.252]	[0.275]	[0.249]	[0.237]
Owned plot >5 years	0.006	0.003	-0.001	0.006	0.001
	(0.006)	(0.008)	(0.010)	(0.008)	(0.009)
	[0.326]	[0.665]	[0.942]	[0.448]	[0.900]
Rented out, farmer	0.003	0.010	0.014	0.011	0.014
	(0.005)	(0.008)	(0.008)	(0.008)	(0.008)
	[0.499]	[0.223]	[0.075]	[0.200]	[0.072]
Slope	-0.002	-0.001	0.003	-0.001	0.003
	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)
	[0.720]	[0.914]	[0.565]	[0.924]	[0.555]
Command area	-0.006	-0.010	-0.001		
	(0.016)	(0.020)	(0.020)		
	[0.720]	[0.619]	[0.970]		
Omnibus F-stat [p]	0.7	0.9	1.1	1.0	1.0
	[0.672]	[0.515]	[0.344]	[0.459]	[0.449]
Controls					
SP CA	X	X	X	X	X
SP CA * Asset index	X	X	X	X	X
# of HH members	X	X	X	X	X
Asset index	X	X	X	X	X
Site FE		X		X	
SP distance to boundary		X	X	X	X
SP log GPS area				X	X
LOP log GPS area				X	X
LOP CA				X	X
Spatial FE			X		X

Table S23: Balance: Largest other plot characteristics (Asset index heterogeneity)

	Full sample	Discontinuity sample			
	SP CA * Asset index Coef. (SE) [p-value]	SP CA * Asset index Coef. (SE) [p-value]			
	(1)	(2)	(3)	(4)	(5)
Dep. var. (LOP, Landsat)					
100 * NDVI (pre-2009)	0.002	-0.036	0.094	-0.042	0.096
	(0.173)	(0.183)	(0.154)	(0.181)	(0.152)
	[0.993]	[0.845]	[0.542]	[0.816]	[0.528]
100 * NDVI (pre-2009, Dry)	0.069	0.031	0.129	0.030	0.133
	(0.190)	(0.204)	(0.176)	(0.196)	(0.174)
	[0.716]	[0.879]	[0.464]	[0.879]	[0.445]
100 * NDVI (pre-2009, Rainy)	-0.021	-0.054	0.080	-0.063	0.082
	(0.177)	(0.190)	(0.166)	(0.191)	(0.165)
	[0.905]	[0.775]	[0.631]	[0.739]	[0.619]
Dep. var. (LOP, Baseline)					
log GPS area	0.065	0.182	0.159		
	(0.076)	(0.093)	(0.090)		
	[0.392]	[0.051]	[0.078]		
Own plot	-0.009	-0.020	-0.008	-0.024	-0.012
	(0.019)	(0.025)	(0.028)	(0.025)	(0.028)
	[0.637]	[0.416]	[0.779]	[0.344]	[0.674]
Owned plot >5 years	-0.016	-0.026	-0.011	-0.032	-0.017
	(0.014)	(0.015)	(0.015)	(0.015)	(0.016)
	[0.243]	[0.081]	[0.472]	[0.034]	[0.261]
Rented out, farmer	-0.011	-0.033	-0.037	-0.033	-0.036
	(0.011)	(0.014)	(0.015)	(0.013)	(0.015)
	[0.318]	[0.015]	[0.018]	[0.015]	[0.019]
Slope	0.003	0.004	0.011	0.003	0.011
	(0.009)	(0.009)	(0.013)	(0.009)	(0.012)
	[0.685]	[0.628]	[0.363]	[0.727]	[0.389]
Command area	-0.033	-0.023	-0.033		
	(0.031)	(0.039)	(0.037)		
	[0.294]	[0.553]	[0.366]		
Omnibus F-stat [p]	0.8	1.7	1.5	2.0	1.5
	[0.606]	[0.084]	[0.151]	[0.061]	[0.179]
Controls					
SP CA	X	X	X	X	X
SP CA * # of HH members	X	X	X	X	X
Asset index	X	X	X	X	X
# of HH members	X	X	X	X	X
Site FE		X		X	
SP distance to boundary		X	X	X	X
SP log GPS area				X	X
LOP log GPS area				X	X
LOP CA				X	X
Spatial FE			X		X

Supplementary Appendix I Household size, wealth, and agricultural production decisions

In Section 5, we assume that household size and the asset index act as shifters of the household's availability of labor and ability to purchase inputs, respectively. Alternatively phrased, they decrease the household's shadow wage and shadow price of inputs, respectively. We should therefore expect larger households to use more household labor and less hired labor. We should also expect wealthier households to use more inputs and more hired labor.

We test this assumption by correlating household size and the asset index with household labor use, input expenditures, and hired labor expenditures. Specifically, we estimate

$$y_{pist} = \beta_1 \# \text{ of HH members}_i + \beta_2 \text{Asset index}_i + X'_{pis}\gamma + \alpha_{st} + \epsilon_{pist} \tag{S1}$$

where y is either household labor use, input expenditures, or hired labor expenditures, on plot p of household i in site s in season t, and α_{st} is a site-by-season fixed effect. We vary the set of controls and fixed effects across specifications to test the robustness of these correlations to omitted household characteristics.

Table S24: Household size and wealth shift agricultural production decisions in a manner consistent with them shifting the shadow wage and shadow price of inputs

	HH labor/ha				Input exp./ha				Hired labor exp./ha			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
# of HH members	7.4		5.0	4.7	0.5		-0.1	-0.0	0.6		-1.1	-0.9
	(1.2)		(1.8)	(1.5)	(0.2)		(0.3)	(0.2)	(0.3)		(0.4)	(0.4)
	[0.000]		[0.004]	[0.002]	[0.010]		[0.840]	[0.951]	[0.077]		[0.013]	[0.028]
Asset index		10.0	4.8	2.5		2.5	1.8	1.5		8.8	8.9	8.4
		(2.7)	(3.2)	(2.7)		(0.4)	(0.5)	(0.4)		(0.7)	(0.8)	(0.7)
		[0.000]	[0.129]	[0.367]		[0.000]	[0.000]	[0.000]		[0.000]	[0.000]	[0.000]
log area	-117.6	-117.4	-118.1	-120.1	-5.3	-5.5	-5.5	-6.1	-3.7	-4.7	-4.5	-5.1
	(4.0)	(4.1)	(4.1)	(3.7)	(0.5)	(0.5)	(0.5)	(0.4)	(0.5)	(0.5)	(0.6)	(0.5)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
# of HH members (15-64)			2.4	2.7			-0.3	-0.4			-0.6	-1.0
			(2.4)	(2.1)			(0.4)	(0.3)			(0.7)	(0.6)
			[0.329]	[0.198]			[0.417]	[0.191]			[0.346]	[0.107]
HHH female			-2.4	4.3			-3.1	-2.0			-0.0	0.7
			(6.4)	(5.8)			(0.9)	(0.8)			(1.4)	(1.3)
			[0.706]	[0.456]			[0.000]	[0.008]			[0.995]	[0.603]
# of plots			-1.4	-0.2			-0.1	0.1			0.2	0.3
			(0.9)	(0.8)			(0.2)	(0.1)			(0.2)	(0.2)
			[0.145]	[0.849]			[0.691]	[0.428]			[0.378]	[0.218]
Site-by-season FE	X	X	X	X	X	X	X	X	X	X	X	X
Site-by-season-by-crop FE				X				X				X
# of observations	28,750	28,717	28,578	28,576	28,823	28,790	28,651	28,649	28,823	28,790	28,651	28,649
# of clusters	1,637	1,635	1,628	1,628	1,637	1,635	1,628	1,628	1,637	1,635	1,628	1,628

We present estimates of Specification S1 in Table S24. Consistent with our predictions, we find that larger households use more household labor and less hired labor, while wealthier households use inputs and more hired labor. These correlations change somewhat when both household size and the asset index are not both included, as household size and the asset index are correlated. This highlights the importance of controlling for the asset index and household size when estimating coefficients on household size and the asset index, respectively, as we do in Section 5. In addition, these correlations are robust to the inclusion of other important household covariates (number of household members (15-64), gender of the household head, and number of plots), and also to the inclusion of site-by-season-by-crop fixed effects. We interpret these results as consistent with household size shifting the shadow wage, and the asset index shifting the shadow price of inputs. In turn, these are consistent with household size shifting the household's availability of labor, and the asset index shifting the household's ability to purchase inputs.

Supplementary Appendix J Model appendix

Derivation of first order conditions. Substitute for L^O using the household labor constraint, $L_1+L_2+\ell+L^O=\overline{L}$, and substitute for c in the household's maximization problem. This leaves two constraints, $M_1+M_2\le\overline{M}$, and $\overline{L}-L_1-L_2-\ell\le\overline{L^O}$; call the multipliers on these constraints $\widetilde{\lambda_M}$ and $\widetilde{\lambda_L}$, respectively. Taking first order conditions yields

$$\begin{array}{rll}(M_k) & \mathbf{E}[u_c\sigma]A_kF_{kM}-\mathbf{E}[u_c]r & =\widetilde{\lambda_M}\\ (L_k) & \mathbf{E}[u_c\sigma]A_kF_{kL}-\mathbf{E}[u_c]w & =-\widetilde{\lambda_L}\\ (\ell) & \mathbf{E}[u_\ell]-\mathbf{E}[u_c]w & =-\widetilde{\lambda_L}\end{array}$$

To ease interpretation, normalize $\lambda_M\equiv\widetilde{\lambda_M}/r\mathbf{E}[u_c]$ and $\lambda_L\equiv\widetilde{\lambda_L}/w\mathbf{E}[u_c]$, and substitute $\mathrm{cov}(\sigma,u_c)=\mathbf{E}[u_c\sigma]-\mathbf{E}[u_c]\mathbf{E}[\sigma]=\mathbf{E}[u_c\sigma]-\mathbf{E}[u_c]$. This yields

$$\begin{array}{rll}(M_k) & \left(1+\frac{\mathrm{cov}(\sigma,u_c)}{\mathbf{E}[u_c]}\right)A_kF_{kM} & =(1+\lambda_M)r\\ (L_k) & \left(1+\frac{\mathrm{cov}(\sigma,u_c)}{\mathbf{E}[u_c]}\right)A_kF_{kL} & =(1-\lambda_L)w\\ (\ell) & \frac{\mathbf{E}[u_\ell]}{\mathbf{E}[u_c]} & =(1-\lambda_L)w\end{array}$$

No constraints. When no constraints bind, as discussed the first order conditions simplify to

$$\begin{aligned}
(M_k) \quad & A_k F_{kM} && = r \\
(L_k) \quad & A_k F_{kL} && = w \\
(\ell) \quad & \tfrac{u_\ell}{u_c} && = w
\end{aligned}$$

Note that the first order conditions for M_2 and L_2 are functions only of (M_2, L_2), and exogenous (A_2, r, w). Therefore, $\frac{dM_2}{dA_1} = \frac{dL_2}{dA_1} = 0$.

Insurance market failure. Consider the case when insurance markets fail. To abstract fully from labor supply, we temporarily remove leisure from the model. To further simplify, we drop other inputs from the production function; when the production function is homogeneous in labor and other inputs, this is without loss of generality. Households solve

$$\begin{aligned}
& \max_{L_1, L_2} \mathbf{E}[u(c)] \\
\sigma(A_1 F_1(L_1) + A_2 F_2(L_2)) - w(L_1 + L_2) + w\overline{L} + r\overline{M} & = c
\end{aligned}$$

To simplify the analysis, this can be rewritten as the two step optimization problem

$$\begin{aligned}
& \max_{L} \mathbf{E}[u(c)] \\
\sigma G(L; A_1) - wL + w\overline{L} + r\overline{M} & = c \\
\max_{L_2} aF_1(L - L_2) + A_2 F_2(L_2) & = G(L; a)
\end{aligned}$$

Next, let $\gamma(g, c) = \frac{\mathbf{E}[u_c(\sigma g + c)]}{\mathbf{E}[\sigma u_c(\sigma g + c)]}$; $\gamma \geq 1$ is the ratio of the marginal utility from consumption to the marginal utility from agricultural production. As above, to represent derivatives of G and γ we use subscripts to indicate partial derivatives and subsume arguments. This yields the first order condition

$$(L) \quad G_L - \gamma(G(L; A_1), w(\overline{L} - L) + r\overline{M})w \quad = 0$$

The central intuition for this case can be captured from just the first order condition: $\overline{L}$ and $\overline{M}$ enter symmetrically into the model, so larger households should respond similarly to richer households. If absolute risk aversion decreases sufficiently quickly (e.g., with CRRA preferences), then for sufficiently high levels of consumption $\mathbf{E}[\sigma u_c] = \mathbf{E}[\sigma]\mathbf{E}[u_c] = \mathbf{E}[u_c] \Rightarrow \gamma = 1$. Therefore, sufficiently wealthy or sufficiently large households should not respond to the sample plot shock. Below, we will maintain the assumption that preferences exhibit decreasing absolute risk aversion, and that $\lim_{c\to\infty} \gamma(g, c) = 1$.

Let FOC_L be the left hand side of the first order condition for the utility maximization problem. Then, an application of the implicit function theorem yields $\frac{dL}{dA_1} = -\frac{d\text{FOC}_L/dA_1}{d\text{FOC}_L/dL}$. Evaluating these derivatives yields

$$\frac{d\text{FOC}_L}{dL} = G_{LL} + \gamma_c w^2 - \gamma_g G_L w$$
$$\frac{d\text{FOC}_L}{dA_1} = G_{La} - \gamma_G G_a$$
$$\frac{dL}{dA_1} = -\frac{G_{La} - \gamma_g G_a}{G_{LL} + \gamma_c w^2 - \gamma_g G_L w}$$

Next, we use the first order condition for constrained production maximization. Some applications of the envelope theorem and taking derivatives yields

$$G_L = A_1 F_{1L}$$
$$G_a = F_1$$
$$G_{La} = F_{1L}(1 - dL_2/dL)$$
$$G_{LL} = A_1 F_{1LL}(1 - dL_2/dL)$$

Lastly, note that $\frac{dL_2}{dA_1} = \frac{dL_2}{dL}\frac{dL}{dA_1} + \frac{dL_2}{da}$, as the increase in A_1 shifts both arguments to G. Let FOC_{L_2} denote the left hand side of the first order condition for constrained production maximization. Then, applications of the implicit function theorem yield

$\frac{dL_2}{dL} = -\frac{d\text{FOC}_{L_2}/dL}{d\text{FOC}_{L_2}/dL_2}$ and $\frac{dL_2}{da} = -\frac{d\text{FOC}_{L_2}/da}{d\text{FOC}_{L_2}/dL_2}$. Additional math yields

$$\begin{aligned}
\text{FOC}_{L_2} &= -aF_{1L} + A_2F_{2L} \\
\frac{d\text{FOC}_{L_2}}{da} &= F_{1L} \\
\frac{d\text{FOC}_{L_2}}{dL} &= -aF_{1LL} \\
\frac{d\text{FOC}_{L_2}}{dL_2} &= aF_{1LL} + A_2F_{2LL} \\
\frac{dL_2}{dL} &= \frac{aF_{1LL}}{aF_{1LL} + A_2F_{2LL}} \\
\frac{dL_2}{da} &= -\frac{F_{1L}}{aF_{1LL} + A_2F_{2LL}}
\end{aligned}$$

substituting these into our expression for $\frac{dL_2}{dA_1}$, and in turn our expressions for derivatives of G (in the numerator), yields

$$\begin{aligned}
\frac{dL_2}{dA_1} &= \frac{-A_1F_{1LL}(G_{La} - \gamma_g G_a) + F_{1L}(G_{LL} + \gamma_c w^2 - \gamma_g G_L w)}{(A_1F_{1LL} + A_2F_{2LL})(G_{LL} + \gamma_c w^2 - \gamma_g G_L w)} \\
&= \frac{(F_{1L}w^2)\gamma_c - (F_{1L}w - F_{1LL}F_1)A_1\gamma_g}{(A_1F_{1LL} + A_2F_{2LL})(G_{LL} + \gamma_c w^2 - \gamma_g G_L w)}
\end{aligned}$$

To sign this expression, note that the denominator is the product of two second order conditions, for utility maximization and for maximization of production subject to $L_1 = L - L_2$; each of these is negative, so the product is positive. Therefore $\text{sign}(dL_2/dA_1) = \text{sign}((F_{1L}w^2)\gamma_c - (F_{1L}w - F_{1LL}F_1)A_1\gamma_g)$. Next, note that $F_{1L}w^2 > 0$ and $-(F_{1L}w - F_{1LL}F_1)A_1 < 0$; therefore one sufficient condition for this derivative to be negative is that $\gamma_c < 0$ and $\gamma_g > 0$; in other words, increasing consumption reduces the marginal utility from consumption relative to the marginal utility from agricultural production, and increasing agricultural production increases the marginal utility from consumption relative to the marginal utility from agricultural production. The former generically holds under decreasing absolute risk aversion, while the latter holds under some restrictions; under these restrictions, $\frac{dL_2}{dA_1} < 0$.

For one sufficient restriction, we follow Karlan et al. (2014) and make restrictions on the distribution of σ. We assume that, for some $k > 1$, $\sigma = k$ with probability $\frac{1}{k}$ ("the good state") and $\sigma = 0$ with probability $\frac{k-1}{k}$ ("the bad state"); i.e., there is a crop failure with probability $\frac{k-1}{k}$. Under this assumption. Next, define $\overline{R} = -\frac{\mathbf{E}[u_c \frac{u_{cc}}{u_c}]}{\mathbf{E}[u_c]}$

to be the household's average risk aversion, and $R_k = -\mathbf{E}[\frac{u_{cc}}{u_c}|\sigma = k]$ to be the household's risk aversion in the good state. Note that by decreasing absolute risk aversion, $R_k < \overline{R}$. From this, it follows that

$$\gamma_c = \frac{\mathbf{E}[u_{cc}]}{\mathbf{E}[\sigma u_c]} - \frac{\mathbf{E}[\sigma u_{cc}]\mathbf{E}[u_c]}{\mathbf{E}[\sigma u_c]^2} = \gamma(R_k - \overline{R}) < 0$$
$$\gamma_g = \frac{\mathbf{E}[\sigma u_{cc}]}{\mathbf{E}[\sigma u_c]} - \frac{\mathbf{E}[\sigma^2 u_{cc}]\mathbf{E}[u_c]}{\mathbf{E}[\sigma u_c]^2} = (k-1)\frac{\mathbf{E}[u_c|\sigma = 0]}{\mathbf{E}[u_c|\sigma = k]}R_k = (k\gamma - 1)R_k > 0$$

Finally, consider the limit as household wealth increases, and assume that agricultural production will not grow infinitely with household wealth; this holds when the marginal product of labor on each plot falls sufficiently quickly and is true of typical decreasing returns to scale production functions. Then, $\lim_{\overline{M}\to\infty} \gamma = 1$ and $\lim_{\overline{M}\to\infty} \gamma_c = \lim_{\overline{M}\to\infty} \gamma_g = 0$, and therefore $\lim_{\overline{M}\to\infty} \frac{dL_2}{dA_1} = 0$. We therefore expect that, heuristically on average, $\frac{d^2 L_2}{dA_1 d\overline{M}} > 0$, as $\frac{dL_2}{dA_1} < 0$ and $\frac{dL_2}{dA_1}$ approaches 0 for large $\overline{M}$. As $\overline{L}$ and $\overline{M}$ enter symmetrically, the same results hold for $\overline{L}$.

Input constraint. When only the input constraint binds, the first order conditions simplify to

$$\begin{array}{rll} (M_k) & A_k F_{kM} & = (1+\lambda_M) r \\ (L_k) & A_k F_{kL} & = w \\ (\ell) & \frac{\mathbf{E}[u_\ell]}{\mathbf{E}[u_c]} & = w \end{array}$$

Note that the choice of leisure does not enter into the first order conditions for M_k or L_k. Substituting $M_2 = \overline{M} - M_1$ yields the following system of equations

$$\begin{aligned} A_1 F_{1M}(M_1, L_1) - (1+\lambda_M) r = 0 \\ A_1 F_{1L}(M_1, L_1) - w = 0 \\ A_2 F_{2M}(\overline{M} - M_1, L_2) - (1+\lambda_M) r = 0 \\ A_2 F_{2L}(\overline{M} - M_1, L_2) - w = 0 \end{aligned}$$

Stack the left hand sides into the vector FOC_M. Define the Jacobian $J_M \equiv D_{(M_1,L_1,\lambda_M,L_2)}\mathrm{FOC}_M$. Applying the implicit function theorem yields $D_{(A_1)}(M_1, L_1, \lambda_M, L_2)' = -J_M^{-1} D_{(A_1)}\mathrm{FOC}_M$.

Some algebra yields

$$
\begin{aligned}
J_M &= \begin{pmatrix} A_1F_{1MM} & A_1F_{1ML} & -r & 0 \\ A_1F_{1ML} & A_1F_{1LL} & 0 & 0 \\ -A_2F_{2MM} & 0 & -r & A_2F_{2ML} \\ -A_2F_{2ML} & 0 & 0 & A_2F_{2LL} \end{pmatrix} \\
D_{(A_1)}\text{FOC}_M &= (F_{1M}, F_{1L}, 0, 0)' \\
\frac{dM_2}{dA_1} &= k_M A_2 F_{2LL} A_1 (F_{1L}F_{1ML} - F_{1M}F_{1LL}) \\
\frac{dL_2}{dA_1} &= -k_M A_2 F_{2ML} A_1 (F_{1L}F_{1ML} - F_{1M}F_{1LL})
\end{aligned}
$$

where k_M is positive.[S2] As $F_{2LL} < 0$, $\text{sign}\left(\frac{dM_2}{dA_1}\right) = -\text{sign}\left(F_{1L}F_{1ML} - F_{1M}F_{1LL}\right)$. This is negative whenever productivity growth on plot 1 would cause optimal input allocations, holding fixed the shadow price of inputs, to increase on plot 1. Similarly, $\text{sign}\left(\frac{dL_2}{dA_1}\right) = \text{sign}(F_{2LM})\text{sign}\left(\frac{dM_2}{dA_1}\right)$. The labor response and input response on the second plot have the same sign whenever labor and inputs are complements on the second plot.

Labor constraint. When only the labor constraint binds, the first order conditions simplify to

$$
\begin{aligned}
(M_k) \quad & A_kF_{kM} && = r \\
(L_k) \quad & A_kF_{kL} && = (1-\lambda_L)w \\
(\ell) \quad & \tfrac{u_\ell}{u_c} && = (1-\lambda_L)w
\end{aligned}
$$

[S2] $k_M = -\frac{1}{(A_1F_{1LL})A_2^2(F_{2MM}F_{2LL}-F_{2ML}^2)+(A_2F_{2LL})A_1^2(F_{1MM}F_{1LL}-F_{1ML}^2)}$. We make standard assumptions required for unconstrained optimization; second order conditions for unconstrained optimization imply k_M is positive.

Substituting $\ell = \overline{L} - L^O - L_1 - L_2$ and $L^O = \overline{L^O}$, and some rearranging yields

$$
\begin{aligned}
A_1 F_{1M}(M_1, L_1) - r = 0 \\
A_1 F_{1L}(M_1, L_1) - (1 + \lambda_L) w = 0 \\
A_2 F_{2M}(M_2, L_2) - r = 0 \\
A_2 F_{2L}(M_2, L_2) - (1 + \lambda_L) w = 0
\end{aligned}
$$

$$
u_\ell \left(\sum_{k \in \{1,2\}} A_k F_k(M_k, L_k) + r(\overline{M} - M_1 - M_2) + w\overline{L^O}, \overline{L} - \overline{L^O} - L_1 - L_2 \right) -
$$

$$
(1 + \lambda_L) w u_c \left(\sum_{k \in \{1,2\}} A_k F_k(M_k, L_k) + r(\overline{M} - M_1 - M_2) + w\overline{L^O}, \overline{L} - \overline{L^O} - L_1 - L_2 \right) = 0
$$

Stack the left hand sides into the vector FOC_L.

Additionally, it will be convenient to define the following derivatives of on farm labor demand on plot k, LD_k, with respect to the shadow wage w^* and productivity A_k, on farm input demand on plot k, MD_k, with respect to productivity A_k, and on farm labor supply, LS, with respect to the shadow wage w^* and consumption (through shifts to wealth) c. Let

$$
\begin{aligned}
\mathrm{LD}_{kw^*} &= \frac{A_k F_{kMM}}{A_k^2 (F_{kMM} F_{kLL} - F_{kML}^2)} \\
\mathrm{LD}_{kA_k} &= \frac{A_k F_{kM} F_{kML} - A_k F_{kL} F_{kMM}}{A_k^2 (F_{kMM} F_{kLL} - F_{kML}^2)} \\
\mathrm{MD}_{kA_k} &= \frac{A_k F_{kL} F_{kML} - A_k F_{kM} F_{kLL}}{A_k^2 (F_{kMM} F_{kLL} - F_{kML}^2)} \\
\mathrm{LS}_{w^*} &= -\frac{u_c}{u_{\ell\ell} - (1 + \lambda_L) w u_{c\ell}} \\
\mathrm{LS}_c &= -\frac{u_{c\ell} - (1 + \lambda_L) w u_{cc}}{u_{\ell\ell} - (1 + \lambda_L) w u_{c\ell}}
\end{aligned}
$$

We make standard assumptions required for unconstrained optimization; these imply LD_{kw^*} is negative (labor demand decreasing in shadow wage), and LS_{w^*} is positive (labor supply increasing in shadow wage). We further assume LD_{kA_k} and MD_{kA_k} are positive (labor demand and input demand are increasing in productivity); an additional sufficient assumption for this is that F is homogeneous. We further assume LS_c is negative (labor supply is decreasing in wealth); an additional sufficient assumption for this is that u is additively separable in c and ℓ.

Next, define the Jacobian $J_L \equiv D_{(M_1,L_1,M_2,L_2,\lambda_L)}\mathrm{FOC}_L$. Some algebra yields

$$J_L = \begin{pmatrix} A_1F_{1MM} & A_1F_{1ML} & 0 & 0 & 0 \\ A_1F_{1ML} & A_1F_{1LL} & 0 & 0 & -w \\ 0 & 0 & A_2F_{2MM} & A_2F_{2ML} & 0 \\ 0 & 0 & A_2F_{2ML} & A_2F_{2LL} & -w \\ \frac{d\mathrm{FOC}_{L,\ell}}{dM_1} & \frac{d\mathrm{FOC}_{L,\ell}}{dL_1} & \frac{d\mathrm{FOC}_{L,\ell}}{dM_2} & \frac{d\mathrm{FOC}_{L,\ell}}{dL_2} & -wu_c \end{pmatrix}$$

$$\frac{d\mathrm{FOC}_{L,\ell}}{dM_1} = A_1F_{1M}(u_{c\ell} - (1+\lambda_L)wu_{cc})$$
$$\frac{d\mathrm{FOC}_{L,\ell}}{dL_1} = A_1F_{1L}(u_{c\ell} - (1+\lambda_L)wu_{cc}) - (u_{\ell\ell} - (1+\lambda_L)wu_{c\ell})$$
$$\frac{d\mathrm{FOC}_{L,\ell}}{dM_2} = A_2F_{2M}(u_{c\ell} - (1+\lambda_L)wu_{cc})$$
$$\frac{d\mathrm{FOC}_{L,\ell}}{dL_2} = A_2F_{2L}(u_{c\ell} - (1+\lambda_L)wu_{cc}) - (u_{\ell\ell} - (1+\lambda_L)wu_{c\ell})$$

Applying the implicit function theorem yields $D_{(A_1)}(M_1, L_1, M_2, L_2, \lambda_L)' = -J_L^{-1}D_{(A_1)}\mathrm{FOC}_L$. Some further algebra, and substitution, yields

$$D_{(A_1)}\mathrm{FOC}_L = (F_{1M}, F_{1L}, 0, 0, (u_{c\ell} - (1+\lambda_L)wu_{cc})F_1)'$$
$$\frac{dL_2}{dA_1} = \mathrm{LD}_{2w^*}\frac{\mathrm{LD}_{1A_1} - \mathrm{LS}_c(F_{1M}\mathrm{MD}_{1A_1} + F_{1L}\mathrm{LD}_{1A_1} + F_1)}{\mathrm{LS}_{w^*} - (\mathrm{LD}_{1w^*} + \mathrm{LD}_{2w^*}) - \mathrm{LS}_c(\mathrm{LD}_{1A_1} + \mathrm{LD}_{2A_2})}$$
$$\frac{dL_2}{d\bar{L}} = \mathrm{LD}_{2w^*}\frac{1}{\mathrm{LS}_{w^*} - (\mathrm{LD}_{1w^*} + \mathrm{LD}_{2w^*}) - \mathrm{LS}_c(\mathrm{LD}_{1A_1} + \mathrm{LD}_{2A_2})}$$
$$\frac{dL_2}{d\bar{M}} = \mathrm{LD}_{2w^*}\frac{r\mathrm{LS}_c}{\mathrm{LS}_{w^*} - (\mathrm{LD}_{1w^*} + \mathrm{LD}_{2w^*}) - \mathrm{LS}_c(\mathrm{LD}_{1A_1} + \mathrm{LD}_{2A_2})}$$

$\frac{dL_2}{dA_1} < 0$; for interpretation, note that this expression is the derivative of labor demand on plot 2 with respect to the shadow wage, times the effect of the shock to A_1 on the shadow wage. The numerator of the latter is the effect the shock on negative residual labor supply through direct effects (LD_{1A_1}) and wealth effects, including through adjustments of labor and inputs ($-\mathrm{LS}_c(F_{1M}\mathrm{MD}_{1A_1} + F_{1L}\mathrm{LD}_{1A_1} + F_1)$). The denominator of the latter is the derivative of residual labor supply with respect to the shadow wage, adjusted for wealth effects ($\mathrm{LS}_{w^*} - (\mathrm{LD}_{1w^*} + \mathrm{LD}_{2w^*}) - \mathrm{LS}_c(\mathrm{LD}_{1A_1} + \mathrm{LD}_{2A_2})$).

The signs of $\frac{d^2L_2}{d\bar{L}dA_1}$ and $\frac{d^2L_2}{d\bar{M}dA_1}$ are ambiguous. However, unlike the cases of input market failures or insurance market failures, here these second derivatives may have opposite signs. To see one example of this, consider a case where on farm labor and input demands are approximately linear in the shadow wage and productivity, and on farm labor supply is approximately linear in consumption, but exhibits meaningful curvature with respect to the shadow wage. In this case, sign($\frac{d^2 L_2}{d\bar{L} dA_1}$) = sign $\left(\frac{d}{d\bar{L}} \mathrm{LS}_{w^*}\right)$ and sign($\frac{d^2 L_2}{d\bar{L} dA_1}$) = sign $\left(\frac{d}{d\bar{M}} \mathrm{LS}_{w^*}\right)$. To focus on one case, larger households are less responsive to the A_1 shock ($\frac{d^2 L_2}{d\bar{L} dA_1} > 0$) if and only if they are on a more elastic portion of their labor supply curve ($\frac{d}{d\bar{L}} \mathrm{LS}_{w^*} > 0$). That larger households, with more labor available for agriculture, or poorer households, who likely have fewer productive opportunities outside agriculture, would be on a more elastic portion of their labor supply curve is consistent with proposed models of household labor supply dating back to Lewis (1954). This motivates the prediction we focus on: that larger households should be less responsive to the A_1 shock, and richer households should be more responsive to the A_1 shock.

Supplementary Appendix J.1 Testing for binding constraint with crop choice

Supplementary Appendix J.1.1 Model featuring crop choice

Households have 2 plots, indexed by k: $k = 1$ indicates the sample plot, while $k = 2$ indicates the largest other plot. On each plot k, they have access to two production technologies, corresponding to horticulture and bananas. The technology for horticulture production is $\sigma A_k^H F_k^H(M_k, L_k, z_k)$, where A_k^H is plot horticulture productivity, M_k is inputs applied to horticulture on plot k, and L_k is household labor applied to plot k. The production shock σ is a random variable with mean normalized to 1.[S3] Utilizing subscripts to indicate partial derivatives and subsuming arguments we assume marginal products are strictly positive ($F_{kM}^H > 0, F_{kL}^H > 0, F_{kz}^H > 0$), marginal products are increasing in the use of other inputs ($F_{kML}^H > 0, F_{kMz}^H > 0, F_{kLz}^H > 0$), and the production technology is strictly concave ($F_{kMM}^H < 0, F_{kLL}^H < 0, F_{kzz}^H < 0, F_{kMM}^H F_{kLL}^H - (F_{kLM}^H)^2 > 0, \dots$). The technology for banana production is $F_k^B(1-z_k)$. We make the simplifying assumption that banana production only uses land as an input, consistent with the very low input and labor use associated with banana produc-

[S3] While we refer to σ as a production shock, this incorporates general uncertainty in the value of production which includes joint price and production risk.

tion that we document. We make the additional simplifying assumption that banana production is riskless, consistent with qualitative work suggesting that horticultural production is particularly risky because of both production risk and marketing risk. In addition, we allow other costs and benefits of allocating land to bananas relative to horticulture, $C_k^B(1-z_k)$, which includes rainy season production of bananas. We further assume $F_{kz}^B > 0, F_{kzz}^B < 0, C_{kz}^B > 0, C_{kzz}^B > 0$. Within this framework, we model irrigation access on plot k as an increase in horticultural productivity A_k^H from 0.[S4] Note that this implies that during the dry season, households will not cultivate horticulture, use labor, or use inputs on plots outside the command area, consistent with our results in Section 3.

Households have a budget of $\overline{M}$ which, if not utilized for inputs, can be invested in a risk-free asset which appreciates at rate r. In this context, households maximize expected utility over consumption c and leisure l, considering their budget constraint and a labor constraint $\overline{L}$ which is allocated to labor on each plot, leisure, and up to $\overline{L^O}$ units of off farm labor L^O.[S5]

Households maximize expected utility

$$M_1, M_2, L_1, L_2, z_1, z_2, l, L^O E[u(c,l)]$$

subject to the constraints enumerated above

$$\begin{aligned} \sigma(A_1^H F_1^H(M_1, L_1, z_1) + A_2^H F_2^H(M_2, L_2, z_2)) + F_1^B(1-z_1) - C_1^B(1-z_1) + \\ F_2^B(1-z_1) - C_2^B(1-z_2) + wL^O + r(\overline{M} - M_1 - M_2) = c \\ M_1 + M_2 \leq \overline{M} \\ L_1 + L_2 + l + L^O = \overline{L} \\ L^O \leq \overline{L^O} \end{aligned}$$

[S4] One microfoundation of this is that production of horticulture is Leontief in water and the composite $F^H(M_k, L_k, z_k)$. Access to irrigation provides free access to water, which is not traditionally available during the dry season.

[S5] We follow Benjamin (1992) in modeling incomplete labor markets as driven by an off farm labor constraint. As in Benjamin (1992), we do so to match the observation that rural wages appear to be higher than the productivity of on-farm labor. However, for the predictions that follow it is sufficient that the household farm face an upward sloping residual labor supply. This holds if households face a downward sloping labor demand curve (implied by Benjamin (1992); alternatively, Breza et al. (2018) demonstrate the existence of norms driven wage floors), or if households incur convex costs from working off farm (due to distaste from working for others). Alternatively, the market failure may only apply to a particular task, such as managerial labor.

After substituting in the constraints which bind with equality, we derive the following first order conditions

$$(M_k) \quad \left(1+\frac{\text{cov}(\sigma,u_c)}{\mathbf{E}[u_c]}\right) A_k F_{kM} \quad = (1+\lambda_M)r \tag{S2}$$

$$(L_k) \quad \left(1+\frac{\text{cov}(\sigma,u_c)}{\mathbf{E}[u_c]}\right) A_k F_{kL} \quad = (1-\lambda_L)w \tag{S3}$$

$$(z_k) \quad \left(1+\frac{\text{cov}(\sigma,u_c)}{\mathbf{E}[u_c]}\right) A_k F_{kz} \quad = F^B_{kz} - C^B_{kz} \tag{S4}$$

$$(\ell) \quad \frac{\mathbf{E}[u_\ell]}{\mathbf{E}[u_c]} \quad = (1-\lambda_L)w \tag{S5}$$

Supplementary Appendix J.1.2 Model featuring crop choice yields the same predictions

Input or labor constraints To show that the model featuring crop choice yields the same predictions as the model without crop choice, we proceed in 3 steps. First, we define the plot level production function as the envelope of allocations of land across horticulture and bananas, conditional on input and labor choices. Second, we show that second derivatives of this envelope have the same signs as second derivatives of the plot level production function. Third, we note that our results on input and labor constraints in Supplementary Appendix J did not depend on properties of second derivatives of the plot level production function except their sign. Therefore, establishing that the second derivatives of the plot level production function are the same with and without crop choice is sufficient for results in Supplementary Appendix J on input and labor constraints to hold in a model featuring crop choice.

First, let $F_k(M_k, L_k; a) \equiv \max_z aF^H_k(M_k, L_k, z) + F^B_k(1-z) - C^B_k(1-z)$. Applications of the envelope theorem then yield $F_{kM} = A^H_k F^H_M$, $F_{kL} = A^H_k F^H_L$, and $F_{ka} = F^H$.

Second, in three steps we work through each of the second derivatives of F that appear in Supplementary Appendix J. First, we show $F_{kLL} < 0$ and $F_{kMM} < 0$. $F_{kLL} = A^H_k F^H_{kLL} + A^H_k F^H_{kLz} \frac{dz_k}{dL_k}$. An application of the implicit function theorem yields $\frac{dz_k}{dL_k} = -\frac{A^H_k F^H_{kLz}}{A^H_k F^H_{kzz} + F^B_{kzz} - C^B_{kzz}}$. We now make three substitutions. First, we substitute for $\frac{dz_k}{dL_k}$ in our expression for F_{kLL}. Second, we substitute $F^H_{kLL} < (F^H_{kLz})^2/F^H_{1zz}$. Third, we substitute $F^B_{kzz} - C^B_{kzz} < 0$. These substitutions and simplification yield $F_{kLL} < 0$. An identical argument implies $F_{kMM} < 0$.

Second, we show that $F_{kLa} > 0$ and $F_{kMa} > 0$. $F_{kLa} = F^H_{kL} + A^H_k F^H_{kLz} \frac{dz_k}{dA^H_k}$. An application of the implicit function theorem yields $\frac{dz_k}{dA_k^H} = -\frac{F_{kz}^H}{A_k^H F_{kzz}^H + F_{kzz}^B - C_{kzz}^B} > 0$. This yields that $F_{kLa} > 0$. An identical argument implies $F_{kMa} > 0$.

Third, we show that $F_{kLM} > 0$. $F_{kLM} = A_k^H F_{kLM}^H + A_k^H F_{kLz}^H \frac{dz_k}{dM_k}$. An application of the implicit function theorem yields $\frac{dz_k}{dM_k} = -\frac{A_k^H F_{kMz}^H}{A_k^H F_{kzz}^H + F_{kzz}^B - C_{kzz}^B} > 0$. This yields that $F_{kLM} > 0$. As these are all the second derivatives of the plot level production function that entered into our results in Supplementary Appendix J, as noted above this completes the proof.

Insurance constraints Absent perfect insurance and incorporating crop choice into the model, households may now respond to changes in productivity on the sample plot by either shifting land allocated to horticulture or shifting labor allocated to horticulture on each plot. This significantly complicates expressions, so we simplify by abstracting from the choice of inputs and labor and assuming $F_k^H(m, l, z) = F_k^H(z)$. We therefore focus only on statics of substitution related to land allocated to horticulture. As land and labor are complements in the production of horticulture, we expect these results to be robust to allowing for labor and inputs to enter the production function for horticulture. Lastly, to simplify notation, we write $\Pi_k^B \equiv F_k^B - C_k B$. As in Supplementary Appendix J, we abstract from labor supply and remove leisure from the model. Households therefore solve

$$\max_{z_1, z_2} \mathbf{E}[u(c)]$$
$$\sigma(A_1^H F_1^H(z_1) + A_2^H F_2^H(z_2)) + \Pi_1^B(1 - z_1) + \Pi_2^B(1 - z_2) + w\overline{L} + r\overline{M} = c$$

Next, we define $Z_k = -\Pi_k^B(1 - z_k)$. Further, define $F_k^{H*}(Z) = F_k^H(1 - (\Pi_k^B)^{-1}(-Z))$. As Π_k^B is concave, its inverse is convex, so one minus its inverse is concave. F_k^H is concave and increasing. Therefore, F_k^{H*} is concave and increasing. We then rewrite the above problem as

$$\max_{Z_1, Z_2} \mathbf{E}[u(c)]$$
$$\sigma(A_1^H F_1^{H*}(Z_1) + A_2^H F_2^{H*}(Z_2)) - (Z_1 + Z_2) + w\overline{L} + r\overline{M} = c$$

However, this is identical to the setup for insurance constraints in Supplementary Appendix J. Therefore, all results for insurance constraints still hold under the additional assumptions made in Supplementary Appendix J: $\frac{dZ_2}{dA_1^H} < 0$, and $\lim_{\overline{M} \to \inf} \frac{dZ_2}{dA_1^H} = 0$.

Lastly, note that $dZ_k = \Pi^B_{kz} dz_k$. As $\Pi^B_{kz} > 0$, and $\lim_{\overline{M}\to\infty} \Pi^B_{kz} > 0$, it holds that $\frac{dz_2}{dA^H_1} < 0$ and $\lim_{\overline{M}\to\infty} \frac{dz_2}{dA^H_1} = 0$. This completes the proof for allocations to horticulture. Lastly, as noted above, we expect these results to be robust to allowing for labors and inputs to enter the production function for horticulture.

Supplementary Appendix J.1.3 Extensions in model with crop choice

We note two extensions in the model with crop choice. First, as dry season productivity under horticulture is 0 on plots outside the command area, during the dry season households do not cultivate horticulture, apply labor, or apply inputs to plots outside the command area. As a result, we do not expect to see any substitution from largest other plots that are outside the command area, a test we implement in Section 5. Second, that our predictions are robust to flexibly modeling the costs associated with adopting bananas implies our model predictions are robust to any within-plot across-season spillovers caused by the fact that bananas are a perennial crop. Third, predictions on across-plot substitution labor and inputs in Section 4 now also hold for land allocated to horticulture; intuitively, this is because horticulture is strongly complementary to labor and inputs. This provides an additional theoretical justification our consideration of horticulture and irrigation as outcomes in our analysis of substitution in Section 5.