

SUPPLEMENTARY INFORMATION FOR:

Flood-tolerant rice reduces yield variability and raises expected yield, differentially benefitting
socially disadvantaged groups

by Manzoor H. Dar, Alain de Janvry, Kyle Emerick, David Raitzer, and Elisabeth Sadoulet

Robustness to plot controls

In Supplementary Table 2 we show that our main regression results are robust to controlling for some observable plot characteristics. In Columns 1-3 we control for plot area, an indicator for medium land, an indicator for upland, an indicator for irrigation access, and an indicator for an owned plot. We also interact these controls with the duration of flooding. Our results with the addition of these controls remain similar to those in Table 1 of the main text.

One important consideration is that the minikit provided is only enough to cultivate a plot of up to approximately 0.2 ha. Supplementary Figure 1 shows the estimated density of plot size for Swarna and Swarna-Sub1 plots. The overlap between the two distributions occurs mostly in the range of 0-0.5 acres (0-0.2 ha). In Columns 4 and 5 of Supplementary Table 2 we limit our sample to plots of 0.5 acres or less. The results are similar in this smaller sample where there is the most overlap between the distributions of plot size.

Correlation between caste and flooding

The full regression results corresponding to Figures 2a and 2b of the main text are displayed in Supplementary Tables 3 and 4. Supplementary Table 5 displays similar regression results for flooding in August 2013.

Historic flood severity

Estimates on the magnitudes of past floods were obtained from the Global Flood Detection System at the Dartmouth Flood Observatory. The measurement site was selected as the nearest site to our study villages. Estimates of flooding magnitude are a normalized z-score of changes in river discharge. Supplementary Figure 4 displays estimates of flooding magnitude.

Randomization verification

In Supplementary Table 6 we show mean values of several variables for treatment and control farmers as well as mean values of village characteristics for treatment and control villages. The similarities between the observable characteristics suggest that both levels of randomization succeeded in generating groups that are similar in characteristics other than access to Swarna-Sub1.

Location of villages

In Supplementary Figure 5 we show a map of the approximate centroids of the 128 villages in the experiment. The villages (dots in the map) are spread across eight blocks. This figure also displays a visualization of the RADARSAT imagery of flooding that is used to estimate the relationship between caste and flooding.

Table 1: Variety types used in regression estimates

	Percent of plots
1001	4.07
1009	0.53
1018	3.78
BARSA	0.36
BAUNSAGAJA	1.60
BHUTIA	0.65
DHULIA	0.53
GANJAMGIRI	0.62
GEETANJALI	0.60
GHOSHARA	0.60
GOPALABHOGA	0.53
HIRAKANI	0.45
JAGABANDHU	0.55
JONGLIJOTA	0.96
KALACHAMPA	1.22
KALAKATIKI	1.84
KATAKI	0.53
KHADIASOLA	3.01
MAHALAXMI	0.81
MOTI	1.08
MUGEI	1.15
NIRANJAN	1.60
OTHER MODERN	3.52
OTHER TRADITIONAL	6.62
PARBATI	2.53
PARIJAT	0.48
PATINI	0.60
PRATIKSHYA	0.93
PUJA	3.92
SWARNA	46.87
SWARNA-SUB1	7.48
Total	100.00

Table displays the plot-level frequency of the main rice varieties grown by farmers in the sample. The total number of plots is 4,182.

Table 2: Robustness of Swarna-Sub1 yield impact

	All plots		Plot Area ≤ 0.5 Acres		
	(1)	(2)	(3)	(4)	(5)
Swarna-Sub1	167.63 (130.38)	-206.44 (162.46)	-298.38* (169.72)	-118.03 (166.07)	-203.08 (161.32)
Other modern variety	-200.88*** (73.48)	-297.27*** (112.57)	-297.32*** (112.56)	-560.38*** (160.50)	-508.07*** (150.12)
Traditional variety	-472.39*** (125.18)	-863.66*** (173.69)	-860.50*** (173.80)	-1038.93*** (255.23)	-978.08*** (229.45)
Days flood	-63.39*** (16.25)	-71.54*** (23.78)	-68.02** (30.64)	-92.55*** (26.41)	-65.71 (45.92)
Swarna-Sub1*Days flood		69.21*** (22.73)	93.00*** (27.14)	71.54** (28.61)	79.41*** (29.64)
Traditional variety*Days flood		55.01*** (16.63)	54.88*** (16.55)	45.53* (24.82)	57.03** (24.96)
Other modern variety*Days flood		19.80* (11.12)	19.85* (11.11)	44.46*** (16.89)	44.69*** (16.75)
(Days flood-12)*1 if Days flood > 12			-1.83 (37.75)	27.97 (45.41)	-19.64 (51.55)
Swarna-Sub1*(Days flood-12)*1 if Days flood > 12			-199.94*** (65.08)	-171.32*** (60.21)	-177.68*** (63.02)
Block Fixed Effects	Yes	Yes	Yes	Yes	Yes
Plot Controls	Yes	Yes	Yes	No	Yes
Plot Controls*Days Flood	No	Yes	Yes	No	Yes
Mean of Dep Variable	2221.76	2221.76	2221.76	2440.47	2450.03
Number of Observations	4138	4138	4138	2255	2226
R squared	0.464	0.472	0.473	0.373	0.398

All columns present OLS regression results where the dependent variable is rice yield in kg per ha. Plot controls are area, indicator for medium land, indicator for upland, indicator for irrigation access, and indicator for an owned plot. Columns 4 and 5 limit to plots of 0.5 acres or less (see Supplementary Fig. 1). Robust standard errors clustered at the village level are reported in parentheses. Asterisks indicate statistical significance at the 1% ***, 5% **, and 10% * levels.

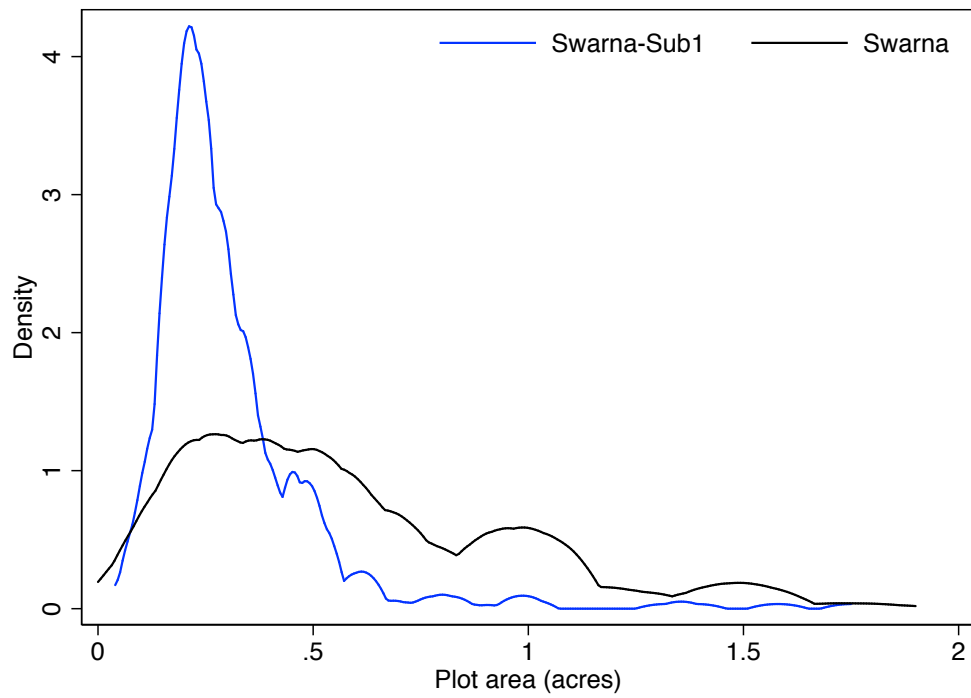


Figure 1: Estimated kernel density of plot area (in acres) for plots cultivated with Swarna and Swarna-Sub1. 102 plots of 2 acres or more are not included in the density estimates.

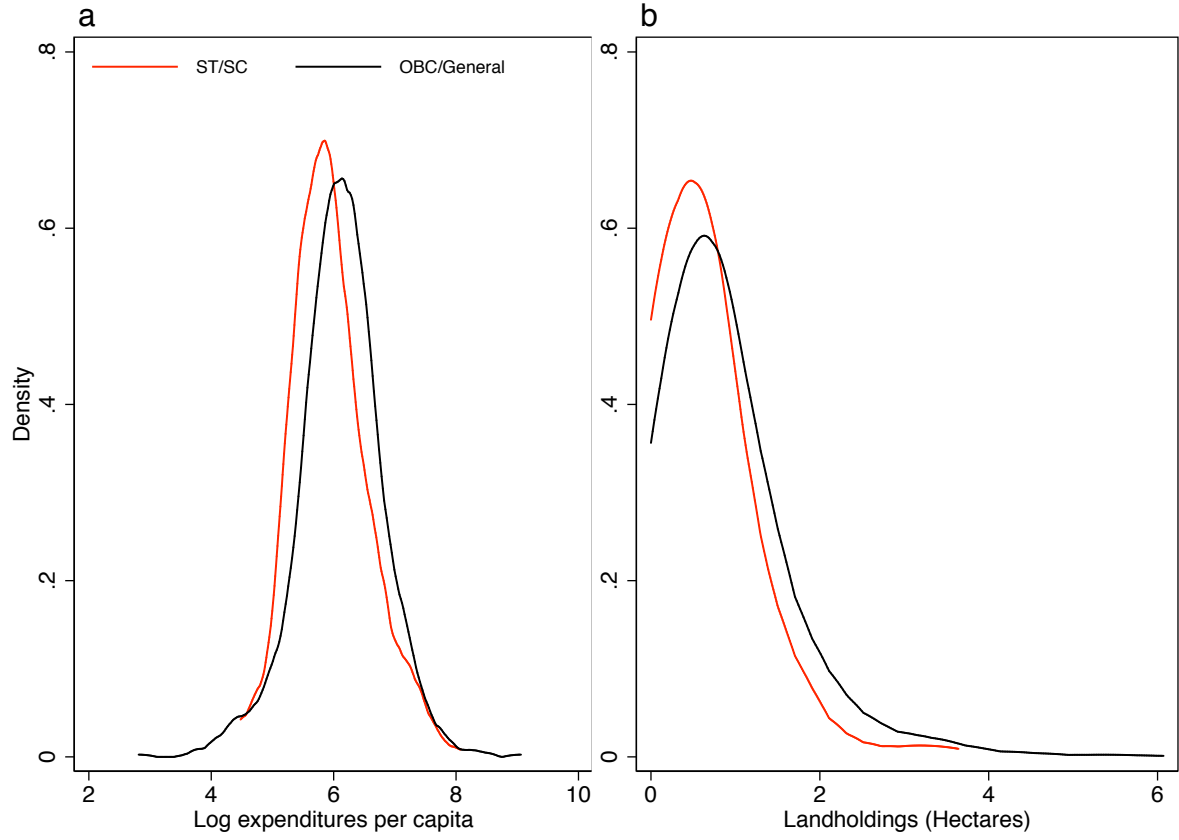


Figure 2: Estimated kernel densities of monthly expenditures per household member (Panel A) and landholdings (Panel B). Densities are estimated separately for SC/ST and OBC/General castes. Red curves are for ST/SC and black curves are for OBC/General castes. Expenditures in Panel A include rice, flour, vegetables, meat, milk, electricity, education, mobile phone minutes, clothing, travel, medicine, and ceremonies.

Table 3: Relationship between caste of cultivator and flood duration during 2011 wet season

	Dependent Variable=Days flood		
	(1)	(2)	(3)
Cultivator is ST or SC	1.83** (0.80)	1.35* (0.69)	1.38** (0.64)
Cultivator is OBC	-0.31 (0.87)	0.14 (0.40)	0.21 (0.40)
Cultivator has below poverty line card			0.05 (0.36)
Education of cultivator			0.05 (0.06)
Cultivator has thatched roof			-0.22 (0.30)
Cultivator has private tubewell			1.26 (0.80)
Cultivator has latrine			-0.54 (0.37)
Village Fixed Effects	No	Yes	Yes
Mean of Dep Variable	8.70	8.70	8.72
Number of Observations	2169	2169	2163
R squared	0.020	0.676	0.679

All columns present OLS regression results where the dependent variable is number of days plot was flooded. Sample consists of 2,169 plots cultivated by 613 surveyed farmers in Bhadrak district. The sample is limited to Bhadrak district because the 2011 floods occurred primarily in Bhadrak. ST refers to Scheduled Tribe, SC to Scheduled Caste, and OBC to Other Backwards Caste. The omitted category is the General caste group. Robust standard errors clustered at the village level are reported in parentheses. Asterisks indicate statistical significance at the 1% ***, 5% **, and 10% * levels.

Table 4: Correlation between village-level caste shares and flooding in September 2008

	Dependent Variable=1 if flooded		
	(1) September 18	(2) September 18-25	(3) September 18-30
ST Share	-0.570*** (0.058)	-0.178*** (0.046)	-0.144*** (0.019)
SC Share	0.153*** (0.056)	0.094** (0.040)	-0.001 (0.025)
Village in Jajpur district	0.123*** (0.024)	0.067*** (0.015)	0.078*** (0.010)
Village in Kendrapara district	0.195*** (0.025)	0.158*** (0.018)	0.085*** (0.010)
Constant	0.235*** (0.021)	0.036*** (0.011)	0.005 (0.006)
Mean of Dep Variable	0.355	0.125	0.053
Number of Observations	4184	4184	4184
R squared	0.052	0.046	0.033

All columns present OLS regressions for villages in Bhadrak, Jajpur, and Kendrapara districts of Orissa India. Excluded caste group in all regressions is OBC/General. Each village is assigned a value of flooded=1 if nearest submerged area within 500 meters of village center. Flood data are from RADARSAT and population data are from the 2001 census. Census data and village locations are taken from geodata@UCBerkeley. Heteroskedasticity robust standard errors are in parentheses. Asterisks indicate statistical significance at the 1% ***, 5% **, and 10% * levels. All regressions are weighted by number of persons in the village dependent on agriculture (number of cultivators + number of agricultural laborers).

Table 5: Correlation between village-level caste shares and flooding in August 2013

	Dependent Variable=1 if flooded	
	(1)	(2)
ST Share	-0.063*** (0.017)	-0.095*** (0.021)
SC Share	0.079*** (0.028)	0.076*** (0.028)
Village in Bhadrak district		0.033* (0.020)
Village in Cuttack district		-0.113*** (0.014)
Village in Jajpur district		-0.094*** (0.015)
Village in Kendrapara district		-0.095*** (0.016)
Constant	0.068*** (0.008)	0.120*** (0.016)
Mean of Dep Variable	0.080	0.080
Number of Observations	8551	8551
R squared	0.005	0.050

Both columns present OLS regressions for villages in Balasore, Bhadrak, Cuttack, Jajpur, and Kendrapara districts of Orissa India. Excluded caste group in all regressions is OBC/General. Each village is assigned a value of flooded=1 if nearest flooded area on August 25th 2013 is within 500 meters of village center. Flood data are from Surface Water Record of the Dartmouth Flood Observatory. A pixel is determined to be flooded if its classification changed from land to water during the previous three days, where daily observations are taken from the NASA MODIS satellite. See <http://floodobservatory.colorado.edu/Version3/080E030Nv3.html> for more information. The population data are from the 2001 census. Census data and village locations are taken from geodata@UCBerkeley. Heteroskedasticity robust standard errors are in parentheses. Asterisks indicate statistical significance at the 1% ***, 5% **, and 10% * levels. All regressions are weighted by number of persons in the village dependent on agriculture (number of cultivators + number of agricultural laborers).

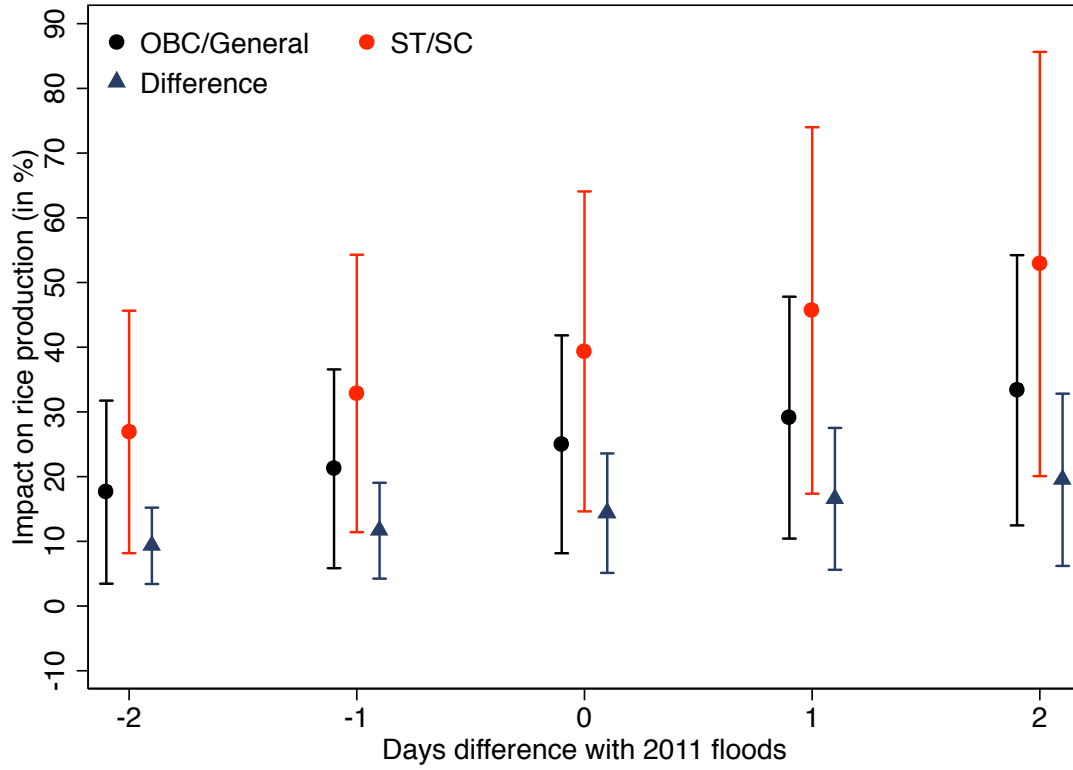


Figure 3: Projected impacts of adoption of flood-tolerant rice (Swarna-Sub1) on rice production in Bhadrak district of Orissa. All estimated production from sharecropped plots cultivated by ST/SC's is assumed to be allocated equally to ST/SC's and higher caste landowners. The simulation is otherwise identical to the simulation in Figure 3 of the main text.

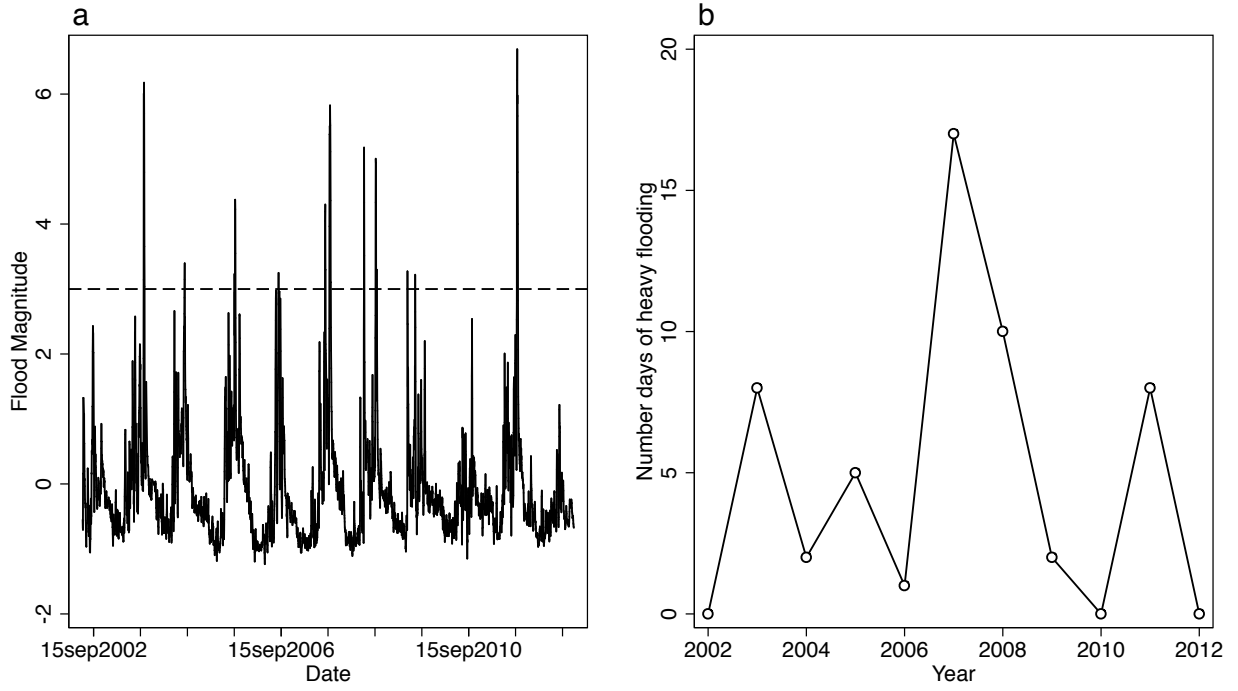


Figure 4: Occurrences of major floods at river discharge site near the Brahmani River in Rajkanika block of Kendrapara district. Site is approximately 6 km from Bhadrak boundary and 9 km from nearest study village. Data are taken from the Dartmouth Flood Observatory (a) Daily river discharge used to measure flooding magnitude from June 2002 to December 2012. Flood magnitude is normalized (z-score). Magnitude above 3 considered to be extreme flooding. (b): Total number of days with extreme flooding (magnitude > 3) for each year.

Table 6: Comparison of observable characteristics in treatment and control households/villages

	Control	Treatment	P-value of difference
<i>Panel A: Farmer Level Statistics</i>			
Land owned in acres	2.002	2.144	0.22
Share of cultivated land w/ irrigation	0.173	0.186	0.57
Sharecropper	0.152	0.178	0.27
HH has private tubewell	0.332	0.325	0.82
Education of farmer	6.896	6.946	0.83
Age of farmer	51.191	51.783	0.44
HH has thatched roof	0.557	0.548	0.78
HH has latrine	0.289	0.354	0.03**
HH has electricity	0.843	0.822	0.38
HH has below poverty line card	0.574	0.559	0.64
ST or SC	0.189	0.176	0.61
<i>Panel B: Village Level Statistics</i>			
Number of households	175.803	179.547	0.91
Population	927.049	974.656	0.79
Number of cultivators	106.443	112.203	0.78
Number of agricultural laborers	53.754	53.031	0.95
Share of village that is SC	0.178	0.229	0.16
Share of village that is ST	0.088	0.091	0.93
Literacy	0.597	0.596	0.98
Approximate elevation (m)	8.393	9.703	0.40

Panel A: Household level statistics for 1,248 households using 2012 survey. Treatment refers to households selected to receive Swarna-Sub1 minikit. Panel B: Village level statistics for 125 villages using 2001 Census of India. 3 of the 128 sample villages were not matched successfully to the 2001 census. Approximate elevation estimated using SRTM digital elevation layer matched to village centroid. Treatment refers to selection of village into treatment group where 5 farmers were selected to receive Swarna-Sub1 minikit. Asterisks indicate statistical significance at the 1% ***, 5% **, and 10% * levels.

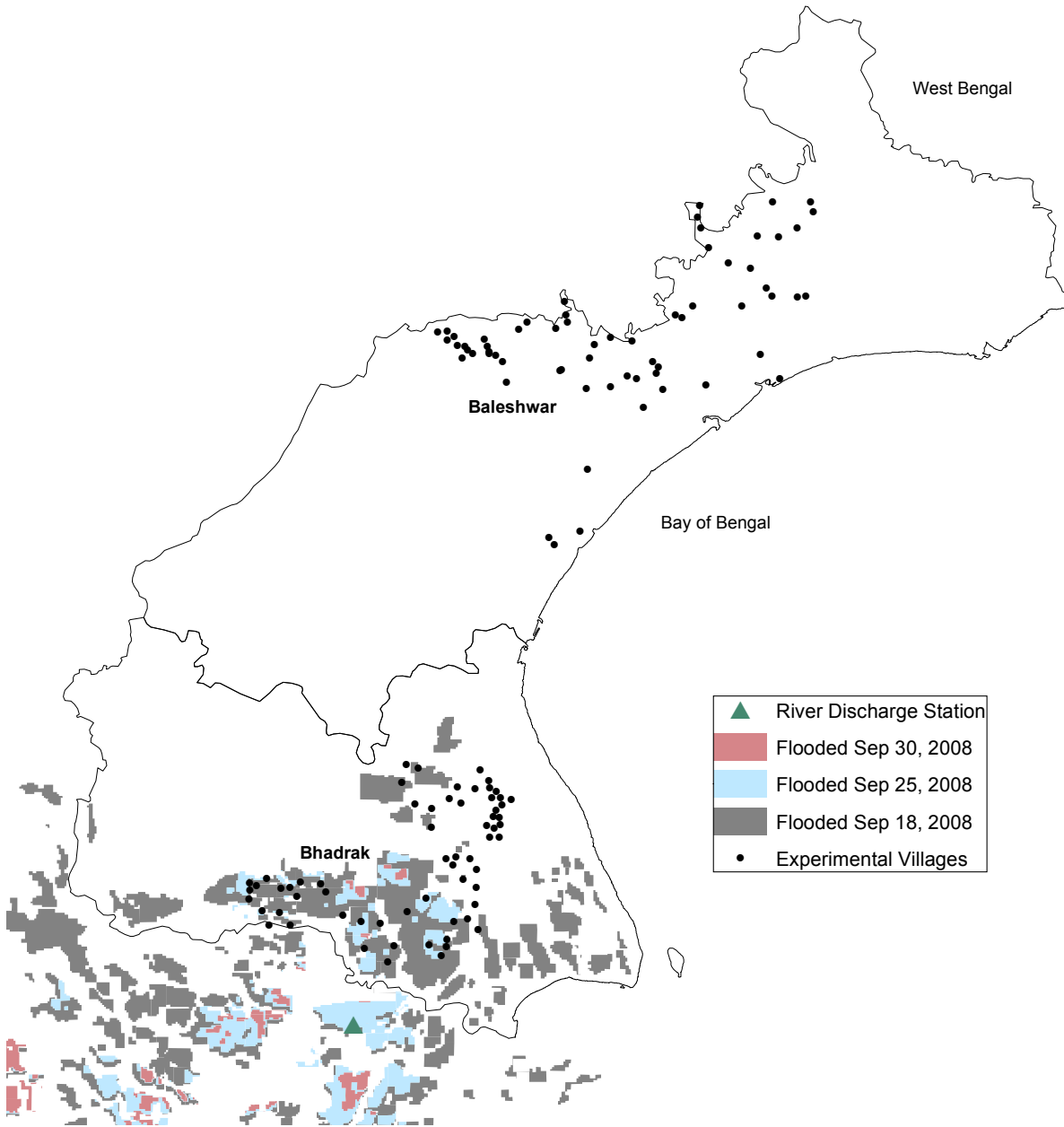


Figure 5: Map of experimental villages and flooding during September 2008. All flood data are from RADARSAT. River discharge station is the location where flood measurements are taken (see Supplementary Fig. 4). The map was generated by the authors using ArcGIS 10.1