SUPPLEMENTARY MATERIALS

Assessing the sustainability of post Green Revolution cereals in India

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Table S1. Nutrient content of monsoon cereals. Values reported in Longvah et al. (1).

Per 100g	Finger millet	Maize	Pearl millet	Rice	Sorghum
Calories (kcal)	320	334	348	356	334
Protein (g)	7.16	8.80	10.96	7.94	9.97
Iron (mg)	4.62	2.49	6.42	0.65	3.95

Table S2. Current status of protein supply and changes under optimization scenarios with state-level calorie supply constraint, constant rabi (winter) cereal production, and constant maize production. Positive values for 'average difference' indicate an increase in protein supply. Units for scenarios are in kilotonnes of protein.

State	Current	MaxProtein	MaxIron	MinWater	MinEnergy	MinGHGs	MaxResilience	Average of Scenarios	Average difference	Average % difference
Andhra Pradesh	677	713	713	712	699	710	698	708	30	4.5
Assam	329	329	329	329	329	329	329	329	0	0.0
Bihar	358	409	403	397	398	402	394	400	43	11.9
Chhattisgarh	415	418	418	418	418	418	418	418	3	0.7
Gujarat	365	412	409	406	332	404	369	389	24	6.5
Haryana	409	457	456	454	448	451	389	442	33	8.1
Himachal Prad.	9	10	9	9	9	9	9	10	0	0.3
Jharkhand	249	299	297	292	250	297	288	287	38	15.3
Karnataka	475	524	489	489	491	500	484	496	21	4.5
Kerala	45	45	45	45	45	45	45	45	0	0.1
Madhya Prad.	201	250	248	232	233	234	224	237	36	17.7
Maharastra	474	515	504	488	437	491	485	487	12	2.6
Odisha	557	565	557	557	557	557	558	558	1	0.3
Punjab	862	863	862	862	862	862	862	862	0	0.0
Rajasthan	558	584	584	583	518	518	534	553	-5	-0.9
Tamil Nadu	509	658	642	616	555	602	551	604	94	18.5
Telangana	394	400	393	392	391	394	395	394	0	-0.1
Uttar Pradesh	1205	1328	1328	1322	1271	1279	1303	1305	100	8.3
Uttarakhand	55	56	55	55	55	55	55	56	0	0.3
West Bengal	1145	1146	1145	1145	1145	1145	1145	1145	0	0.0
INDIA	9293	9982	9885	9801	9444	9701	9534	9725	432	4.7

Table S3. Current status of iron supply and changes under optimization scenarios with state-level calorie supply constraint, constant rabi (winter) cereal production, and constant maize production. Positive values for 'average difference' indicate an increase in iron supply. Units for scenarios are in tonnes of iron.

State	Current	MaxProtein	MaxIron	MinWater	MinEnergy	MinGHGs	MaxResilience	Average of Scenarios	Average difference	Average % difference
Andhra Pradesh	63	113	117	115	98	113	97	109	46	73.1
Assam	27	27	27	27	27	27	27	27	0	0.0
Bihar	30	97	114	98	105	109	98	103	73	243.7
Chhattisgarh	34	39	39	39	39	39	39	39	5	14.8
Gujarat	118	192	199	189	66	188	115	158	40	34.0
Haryana	96	172	181	178	167	171	58	154	58	61.0
Himachal Prad.	1	1	1	1	1	1	1	1	0	25.5
Jharkhand	21	92	93	81	26	93	82	78	57	274.4
Karnataka	117	116	162	155	118	135	150	139	22	19.0
Kerala	4	4	4	4	4	4	4	4	0	2.3
Madhya Prad.	49	109	110	104	104	106	91	104	55	111.4
Maharastra	136	169	176	160	68	152	157	147	11	8.0
Odisha	52	49	54	53	54	54	53	53	1	1.0
Punjab	71	71	71	71	71	71	71	71	0	-0.1
Rajasthan	310	341	341	336	241	239	253	292	-19	-6.0
Tamil Nadu	60	290	306	243	220	299	220	263	203	341.1
Telangana	36	36	40	38	39	39	37	38	2	5.4
Uttar Prad.	189	408	408	393	303	317	360	365	176	93.2
Uttarakhand	11	17	19	19	12	18	19	17	6	50.7
West Bengal	94	94	94	94	94	94	94	94	0	0.0
INDIA	1520	2436	2556	2398	1855	2270	2025	2257	737	48.5

Table S4. Current status of energy demand and changes under optimization scenarios with state-level calorie supply constraint, constant rabi (winter) cereal production, and constant maize production. Negative values for 'average difference' indicate a reduction in energy demand. Units for scenarios are in billion kilowatt hours (10^9 kWh).

State	Current	MaxProtein	MaxIron	MinWater	MinEnergy	MinGHGs	MaxResilience	Average of Scenarios	Average difference	Average % difference
Andhra Pradesh	10.8	10.3	10.2	10.1	9.7	10.3	10.0	10.1	-0.7	-6.2
Assam	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0	0.0
Bihar	3.0	3.0	2.9	2.9	2.7	2.9	2.9	2.9	-0.1	-4.3
Chhattisgarh	4.7	4.6	4.6	4.6	4.6	4.6	4.6	4.6	0.0	-1.0
Gujarat	0.9	1.2	1.1	1.1	0.7	1.1	1.1	1.1	0.1	12.3
Haryana	7.1	3.5	3.3	3.3	2.9	3.0	6.5	3.7	-3.3	-47.0
Himachal Prad.	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.3
Jharkhand	1.2	1.4	1.4	1.4	1.2	1.4	1.4	1.4	0.2	14.2
Karnataka	4.8	5.4	6.6	7.2	3.6	3.9	5.9	5.5	0.7	13.5
Kerala	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.0	-0.1
Madhya Prad.	2.0	1.3	1.3	1.2	1.2	1.2	1.4	1.3	-0.7	-37.0
Maharastra	4.0	4.0	4.0	4.0	3.1	3.5	3.8	3.7	-0.2	-6.0
Odisha	5.1	5.2	5.0	5.2	5.0	5.0	5.1	5.1	0.0	0.1
Punjab	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	0.0	0.0
Rajasthan	1.9	2.1	2.1	2.1	1.3	1.4	2.1	1.8	-0.1	-5.7
Tamil Nadu	8.4	6.4	5.5	6.8	3.6	3.8	4.2	5.0	-3.4	-40.0
Telangana	7.0	7.1	6.7	6.6	6.6	7.1	6.8	6.8	-0.2	-2.9
Uttar Prad.	18.1	14.1	14.1	13.2	11.7	14.6	14.1	13.6	-4.5	-24.7
Uttarakhand	1.0	1.1	1.0	1.0	1.0	1.0	1.0	1.0	0.0	-1.6
West Bengal	5.3	5.4	5.3	5.3	5.3	5.3	5.3	5.3	0.0	0.0
INDIA	102.1	92.7	92.0	93.0	81.1	87.0	93.0	89.8	-12.3	-12.1

Table S5. Current status of GHG emissions and changes under optimization scenarios with state-level calorie supply constraint, constant rabi (winter) cereal production, and constant maize production. Negative values for 'average difference' indicate a reduction in GHG emissions. Units for scenarios are in million tonnes of CO_2 equivalents (Mtonne CO_2eq).

State	Current	MaxProtein	MaxIron	MinWater	MinEnergy	MinGHGs	MaxResilience	Average of Scenarios	Average difference	Average % difference
Andhra Pradesh	16.0	14.5	14.3	14.5	15.0	13.9	14.4	14.4	-1.6	-10.0
Assam	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	0.0	0.0
Bihar	9.2	7.1	6.5	6.5	6.7	6.3	6.6	6.6	-2.5	-27.8
Chhattisgarh	7.7	7.6	7.6	7.6	7.6	7.6	7.6	7.6	-0.1	-1.4
Gujarat	2.8	1.5	1.5	1.5	2.9	1.3	2.8	1.9	-0.9	-31.3
Haryana	6.5	4.1	3.4	4.6	5.1	3.0	5.9	4.4	-2.1	-32.2
Himachal Prad.	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	-1.4
Jharkhand	6.1	3.4	3.3	3.5	5.9	3.3	3.6	3.8	-2.2	-36.8
Karnataka	6.5	6.5	6.1	6.6	5.5	5.1	6.1	6.0	-0.5	-8.1
Kerala	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.0	-0.1
Madhya Prad.	2.7	1.1	1.1	1.1	1.1	1.1	1.4	1.2	-1.6	-57.6
Maharastra	5.2	4.1	4.2	4.4	5.2	3.3	3.8	4.2	-1.1	-20.5
Odisha	9.4	9.6	9.3	9.4	9.3	9.3	9.4	9.4	0.0	0.0
Punjab	17.3	17.4	17.4	17.4	17.4	17.1	17.3	17.3	0.0	0.2
Rajasthan	1.3	1.3	1.3	1.3	1.0	0.8	1.9	1.3	0.0	-2.2
Tamil Nadu	10.2	4.3	3.3	4.9	4.4	2.6	4.4	4.0	-6.2	-60.8
Telangana	9.4	9.6	9.6	9.9	9.9	9.0	9.8	9.6	0.2	2.5
Uttar Prad.	22.6	20.1	20.1	19.8	20.4	18.3	19.9	19.8	-2.8	-12.3
Uttarakhand	0.8	0.8	0.8	0.8	0.8	0.7	0.8	0.8	0.0	-5.4
West Bengal	27.9	27.9	27.9	27.9	27.9	27.9	27.9	27.9	0.0	0.0
INDIA	167.4	146.9	143.6	147.6	151.9	136.8	149.4	146.0	-21.3	-12.8

Table S6. Current status of irrigation (blue) water demand and changes under optimization scenarios with state-level calorie supply constraint, constant rabi (winter) cereal production, and constant maize production. Negative values for 'average difference' indicate a reduction in water demand. Units for scenarios are in cubic kilometers of water (km^3 H_2O).

State	Current	MaxProtein	MaxIron	MinWater	MinEnergy	MinGHGs	MaxResilience	Average of Scenarios	Average difference	Average % difference
Andhra Pradesh	9.6	8.0	7.9	7.8	8.2	8.1	8.3	8.0	-1.5	-15.9
Assam	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.0	0.0
Bihar	6.0	5.3	4.8	4.2	4.2	4.3	4.6	4.6	-1.5	-24.4
Chhattisgarh	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	0.0	0.0
Gujarat	2.4	0.7	0.7	0.4	2.6	0.8	1.5	1.1	-1.3	-53.8
Haryana	4.0	1.7	1.6	1.5	1.7	1.8	3.6	2.0	-2.1	-50.9
Himachal Prad.	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	-4.8
Jharkhand	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
Karnataka	4.7	2.8	2.7	2.2	4.6	3.8	3.2	3.2	-1.5	-31.6
Kerala	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.0	0.0
Madhya Prad.	1.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	-0.5	-52.0
Maharastra	1.2	0.7	0.7	0.6	1.3	1.1	0.8	0.9	-0.3	-28.6
Odisha	6.1	6.2	6.2	5.6	6.2	6.2	6.2	6.1	0.0	-0.3
Punjab	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	0.0	0.0
Rajasthan	0.5	0.2	0.2	0.2	0.6	0.6	0.6	0.4	-0.1	-16.9
Tamil Nadu	11.2	7.3	7.0	6.1	8.1	7.0	7.6	7.2	-4.0	-35.8
Telangana	5.7	5.8	5.4	5.3	5.3	5.8	5.5	5.5	-0.2	-3.8
Uttar Prad.	9.8	6.8	6.8	6.2	5.5	7.5	6.8	6.6	-3.2	-32.6
Uttarakhand	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	-0.1	-16.1
West Bengal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
INDIA	77.3	60.9	59.3	55.4	63.6	62.3	64.3	61.0	-16.3	-21.1

Table S7. Current status of climate resilience and changes under optimization scenarios with state-level calorie supply constraint, constant rabi (winter) cereal production, and constant maize production. Positive values for 'average difference' indicate an increase in climate resilience. Units for scenarios are in trillion calories lost under an historically extreme dry year (10^{12} kcal).

State	Current	MaxProtein	MaxIron	MinWater	MinEnergy	MinGHGs	MaxResilience	Average of Scenarios	Average difference	Average % difference
Andhra Pradesh	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.6	-0.7	0.1	-11.6
Assam	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	0.0	0.0
Bihar	-1.2	-0.7	-0.7	-0.5	-0.7	-0.6	-0.5	-0.6	0.5	-46.5
Chhattisgarh	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	0.0	-1.2
Gujarat	-0.7	-0.6	-0.6	-0.6	-0.6	-0.6	-0.5	-0.6	0.1	-15.6
Haryana	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	0.0	-5.8
Himachal Prad.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-6.0
Jharkhand	-0.5	-0.3	-0.4	-0.3	-0.4	-0.3	-0.2	-0.3	0.1	-29.0
Karnataka	-0.4	-0.5	-0.4	-0.3	-0.4	-0.3	-0.2	-0.4	0.1	-17.3
Kerala	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	-0.3
Madhya Prad.	-0.4	-0.3	-0.2	-0.2	-0.2	-0.2	-0.1	-0.2	0.2	-42.9
Maharastra	-0.4	-0.2	-0.7	-0.3	-0.7	-0.2	-0.1	-0.3	0.1	-21.1
Odisha	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	0.0	-0.7
Punjab	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	0.0	0.0
Rajasthan	-0.7	-0.8	-0.7	-0.7	-0.7	-0.7	-0.2	-0.7	0.1	-10.8
Tamil Nadu	-0.3	-0.3	-0.1	-0.2	-0.1	-0.1	-0.1	-0.1	0.1	-48.0
Telangana	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	0.0	-1.9
Uttar Prad.	-1.9	-1.7	-1.9	-1.7	-1.9	-1.8	-1.6	-1.8	0.2	-9.3
Uttarakhand	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	-27.3
West Bengal	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	0.0	0.0
INDIA	-12.9	-11.6	-12.1	-11.0	-12.1	-11.0	-9.6	-11.2	1.7	-12.9

Table S8. Current status of dimensions and changes under optimization scenarios with state-level calorie supply constraint, constant rabi (winter) cereal production, and constant maize production. Positive percent difference values for protein and iron and negative percent difference values for energy, GHGs, water, irrigation, and resilience indicate an improvement after optimization.

Dimension	Current	% difference from current						
		MaxProtein	MaxIron	MinWater	MinEnergy	MinGHGs	MaxRes	Average
protein (Mtonne)	9.3	7.4	6.4	5.5	1.6	4.4	2.6	4.7
iron (ktonne)	1.5	60.3	68.2	57.8	22.1	49.4	33.2	48.5
energy (10^9 kWh)	102.1	-9.2	-10.0	-9.0	-20.6	-14.9	-8.9	-12.1
GHGs (Mtonne CO_2eq)	167.4	-12.2	-14.2	-11.8	-9.2	-18.3	-10.8	-12.8
water (km^3)	392.1	-7.9	-9.1	-10.2	-4.9	-7.8	-7.1	-7.9
irrigation water (km^3)	77.3	-21.2	-23.3	-28.2	-17.7	-19.3	-16.7	-21.1
resilience (10^{12} kcal lost under extreme dry year)	12.9	-10.3	-6.3	-14.8	-6.3	-14.4	-25.2	-12.9

Table S9. Current status of dimensions and changes under optimization scenarios with national-level calorie supply constraint, constant rabi (winter) cereal production, constant maize production, and historically-based restrictions on maximum coarse cereal area. Positive percent difference values for protein and iron and negative percent difference values for energy, GHGs, water, irrigation, and resilience indicate an improvement after optimization.

Dimension	Current	% difference from current						
		MaxProtein	MaxIron	MinWater	MinEnergy	MinGHGs	MaxRes	Average
protein (Mtonne)	9.3	3.0	1.2	0.8	-1.4	0.4	0.2	0.7
iron (ktonne)	1.5	7.5	15.3	11.3	-14.4	5.4	1.9	4.5
energy (10^9 kWh)	102.1	2.2	-1.3	-0.1	-7.0	-4.2	0.6	-1.6
GHGs (Mtonne CO_2eq)	167.4	0.7	-3.4	-3.2	-0.1	-5.7	-2.0	-2.3
water (km^3)	392.1	-0.2	-1.9	-2.2	0.7	-1.1	-1.2	-1.0
irrigation water (km^3)	77.3	-1.5	-3.7	-4.6	-2.6	-2.5	-1.3	-2.7
resilience (10^{12} kcal lost under extreme dry year)	12.9	0.5	2.5	-3.7	5.3	-2.2	-7.4	-0.8

Table S10. Current status of dimensions and changes under optimization scenarios with national calorie supply constraint, constant rabi (winter) cereal production, and constant maize production. Positive percent difference values for protein and iron and negative percent difference values for energy, GHGs, water, irrigation, and resilience indicate an improvement after optimization.

Dimension	Current	% difference from current						
		MaxProtein	MaxIron	MinWater	MinEnergy	MinGHGs	MaxRes	Average
protein (Mtonne)	9.3	9.4	8.0	6.3	4.1	6.5	4.0	6.4
iron (ktonne)	1.5	72.2	85.1	67.6	46.6	69.6	38.6	63.3
energy (10^9 kWh)	102.1	-11.4	-15.9	-11.3	-27.6	-19.7	-5.2	-15.2
GHGs (Mtonne CO_2eq)	167.4	-14.5	-18.9	-16.4	-15.4	-23.8	-9.6	-16.4
water (km^3)	392.1	-9.3	-11.4	-15.3	-7.5	-11.2	-10.4	-10.8
irrigation water (km^3)	77.3	-25.5	-31.5	-35.3	-26.3	-30.4	-18.5	-27.9
resilience (10^{12} kcal lost under extreme dry year)	12.9	-11.7	-8.8	-19.7	-8.8	-15.8	-31.2	-16.0

Table S11. Current status of dimensions and changes under optimization scenarios with national calorie supply constraint and constant rabi (winter) cereal production. Values include nutrient supply, resource demand, and emissions from maize. Positive percent difference values for protein and iron and negative percent difference values for energy, GHGs, water, irrigation, and resilience indicate an improvement after optimization.

Dimension	Current	% difference from current						
		MaxProtein	MaxIron	MinWater	MinEnergy	MinGHGs	MaxRes	Average
protein (Mtonne)	11.0	19.9	19.0	15.3	8.6	15.1	12.6	15.1
iron (ktonne)	2.0	150.7	153.9	140.7	75.3	127.6	86.2	122.4
energy (10^9 kWh)	117.6	-30.3	-30.4	-34.6	-54.2	-39.6	-28.8	-36.3
GHGs (Mtonne CO_2eq)	179.7	-58.9	-59.4	-59.9	-37.4	-68.3	-56.5	-56.7
water (km^3)	427.0	-37.1	-37.5	-40.4	-23.3	-36.8	-36.4	-35.3
irrigation water (km^3)	78.2	-80.6	-80.7	-85.5	-76.9	-81.2	-83.9	-81.5
resilience (10^{12} kcal lost under extreme dry year)	12.9	-65.3	-36.5	-70.9	-36.5	-65.9	-104.0	-63.2

Table S12. Current status of dimensions and changes under optimization scenarios with national calorie supply constraint and constant maize production. Positive percent difference values for protein and iron and negative percent difference values for energy, GHGs, water, irrigation, and resilience indicate an improvement after optimization.

Dimension	Current	% difference from current						
		MaxProtein	MaxIron	MinWater	MinEnergy	MinGHGs	MaxRes	Average
protein (Mtonne)	9.3	8.5	6.5	6.6	2.7	4.9	4.0	5.5
iron (ktonne)	1.5	83.7	94.8	58.7	49.7	79.4	38.6	67.5
energy (10^9 kWh)	102.1	-15.2	-17.1	-8.2	-31.5	-24.2	-5.2	-16.9
GHGs (Mtonne CO_2eq)	167.4	-19.4	-22.7	-13.8	-18.3	-28.9	-9.6	-18.8
water (km^3)	392.1	-11.7	-14.0	-13.8	-8.3	-13.8	-10.4	-12.0
irrigation water (km^3)	77.3	-32.6	-36.8	-30.7	-30.4	-34.5	-18.5	-30.6
resilience (10^{12} kcal lost under extreme dry year)	12.9	-13.0	-10.9	-17.5	-10.9	-20.4	-31.2	-17.3

Table S13. Current status of dimensions and changes under optimization scenarios with national calorie supply constraint, constant rabi (winter) cereal production, constant maize production, and using states as units of optimization. Positive percent difference values for protein and iron and negative percent difference values for energy, GHGs, water, irrigation, and resilience indicate an improvement after optimization.

Dimension	Current	% difference from current						
		MaxProtein	MaxIron	MinWater	MinEnergy	MinGHGs	MaxRes	Average
protein (Mtonne)	9.3	13.8	11.9	11.0	8.7	5.3	9.1	9.9
iron (ktonne)	1.5	117.9	137.5	114.1	101.8	72.4	95.5	106.5
energy (10^9 kWh)	102.2	-26.5	-37.0	-27.1	-42.2	-23.0	-26.5	-30.4
GHGs (Mtonne CO_2eq)	167.9	-11.3	-19.9	-16.9	-15.6	-28.1	-14.5	-17.7
water (km^3)	392.0	-14.2	-17.0	-20.9	-13.2	-10.9	-16.4	-15.4
irrigation water (km^3)	77.3	-40.6	-47.8	-50.7	-46.2	-32.3	-43.0	-43.4
resilience (10^{12} kcal lost under extreme dry year)	12.7	-23.3	-27.7	-36.9	-21.5	-28.2	-40.1	-29.6

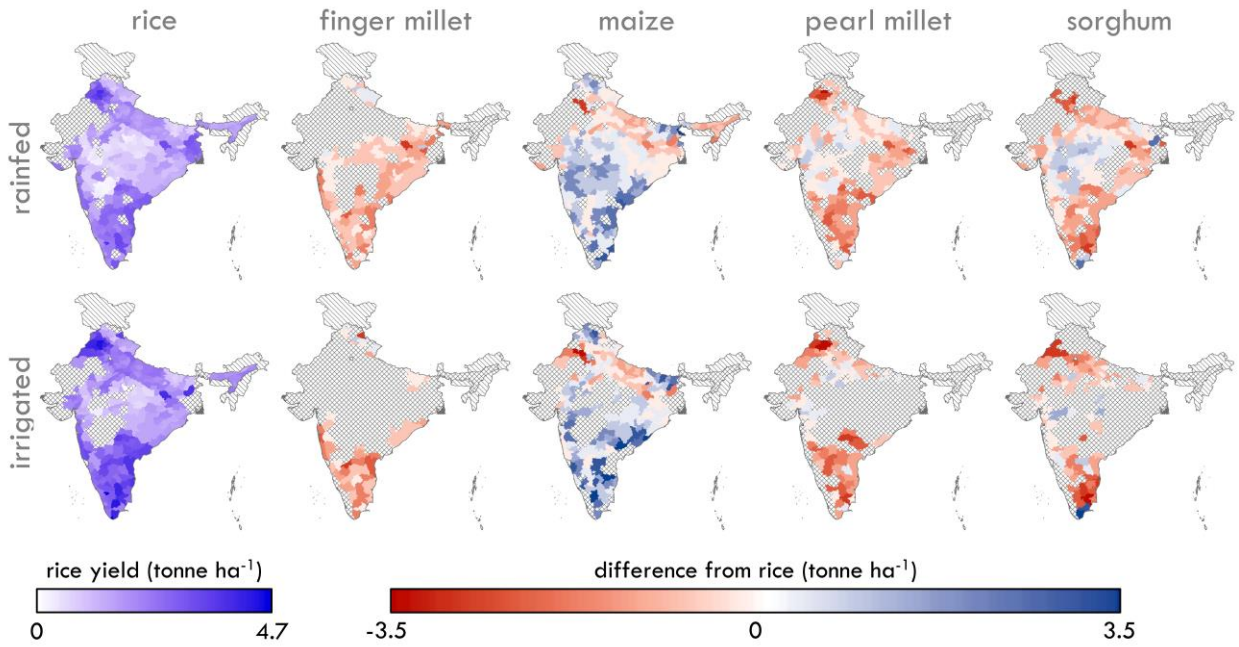

Fig. S1. Comparison of yields for rice and other monsoon cereals. Areas with diagonal hatching had no data. For maps of rice yields, areas with cross-hatching did not produce rice. For maps of yield differences, areas with cross-hatching did not have overlap between rice production and the particular other cereal. Blue areas indicate that the yield of the other cereal was higher than rice in that district. Red areas indicate the opposite.

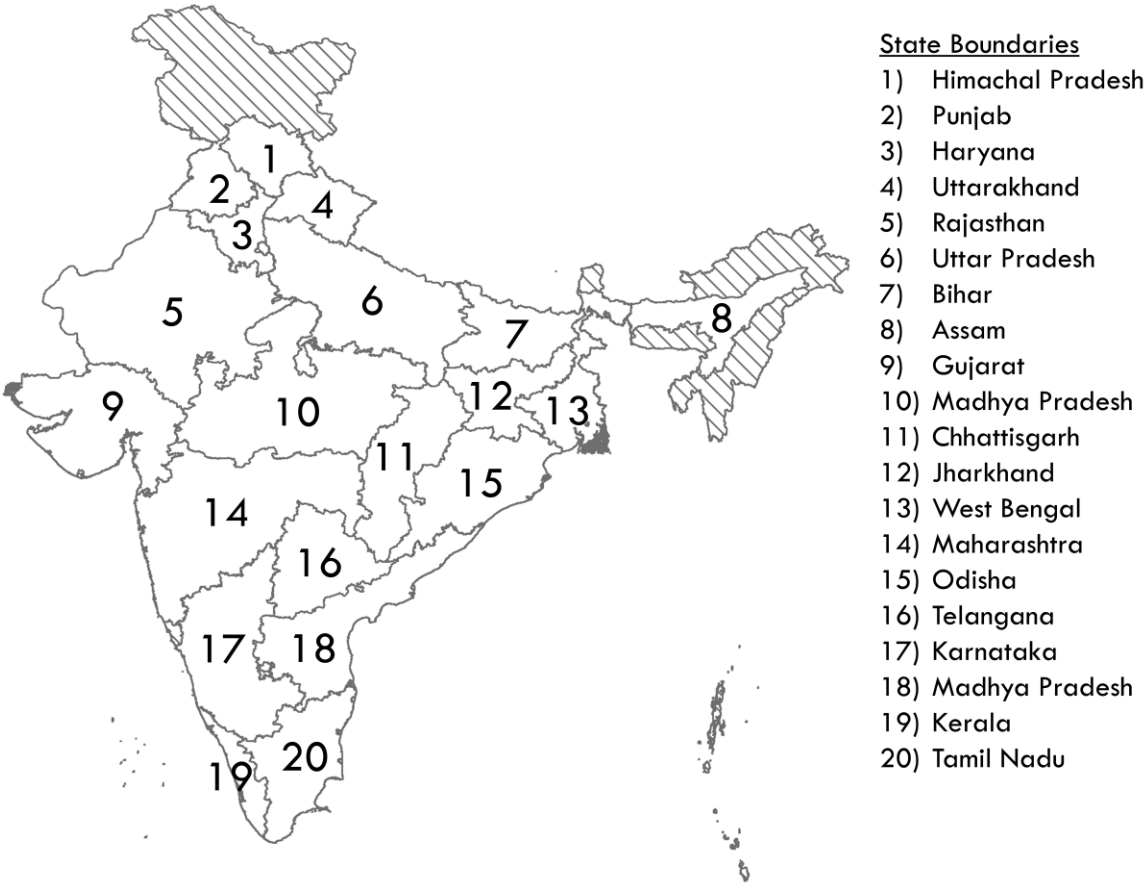

Fig. S2. Map of state boundaries.

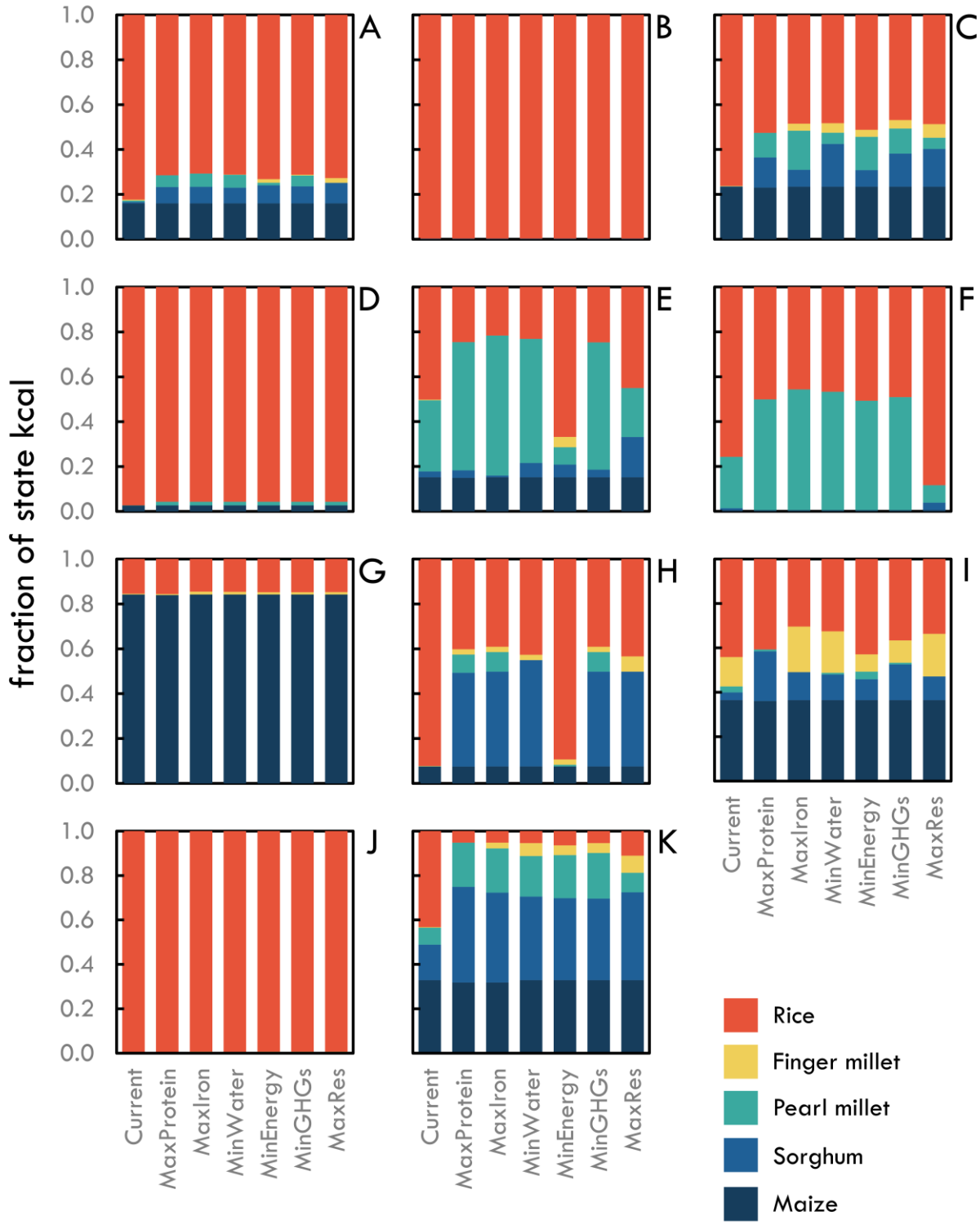

Fig. S3. State-level share of monsoon cereal production under optimizations. Shares shown for (A) Andhra Pradesh, (B) Assam, (C) Bihar, (D) Chhattisgarh, (E) Gujarat, (F) Haryana, (G) Himachal Pradesh, (H) Jharkhand, (I) Karnataka, (J) Kerala, and (K) Madhya Pradesh.

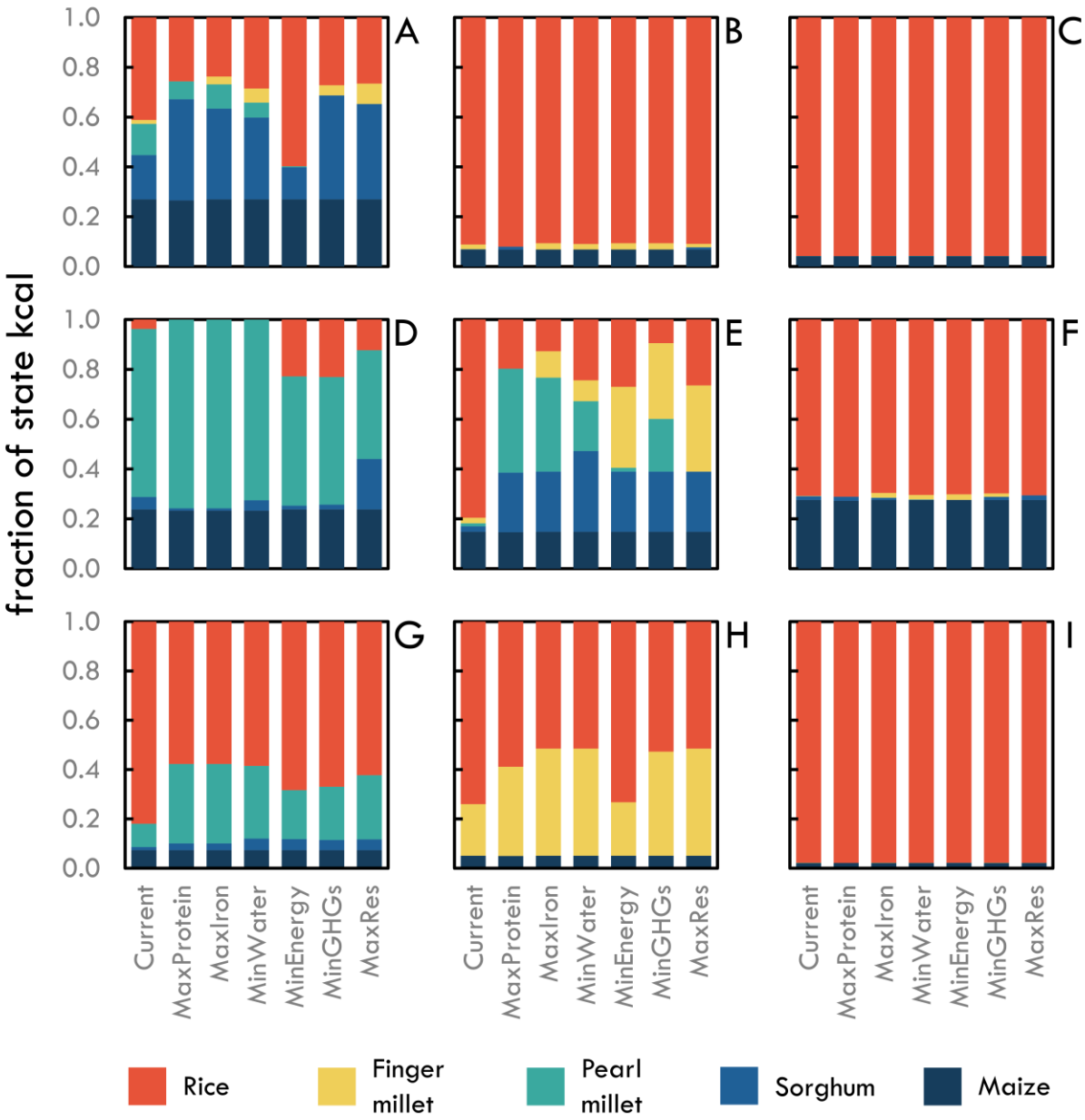

Fig. S4. State-level share of monsoon cereal production under optimizations. Shares shown for (A) Maharashtra, (B) Odisha, (C) Punjab, (D) Rajasthan, (E) Tamil Nadu, (F) Telangana, (G) Uttar Pradesh, (H) Uttarakhand, and (I) West Bengal.

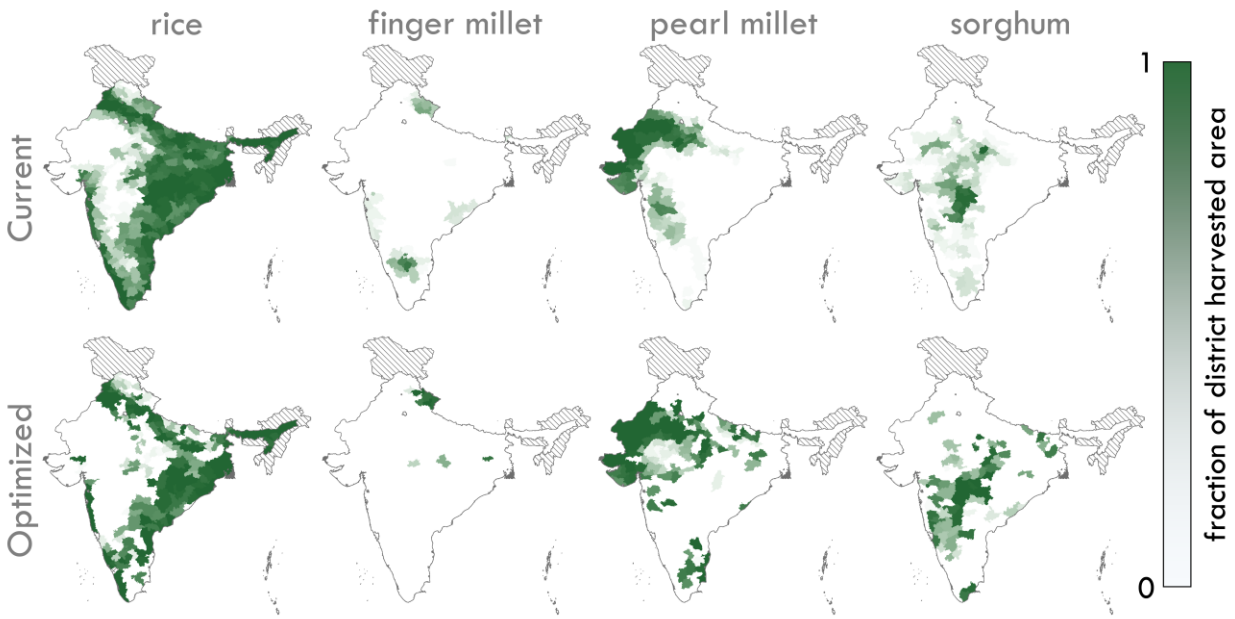

Fig. S5. Allocation of harvested area under current production and under scenario to maximize protein supply. Maps show the fraction of each district's monsoon cereal area allocated to each crop. Areas with diagonal lines indicate places with no data. Maize maps are not shown because maize production was held constant.

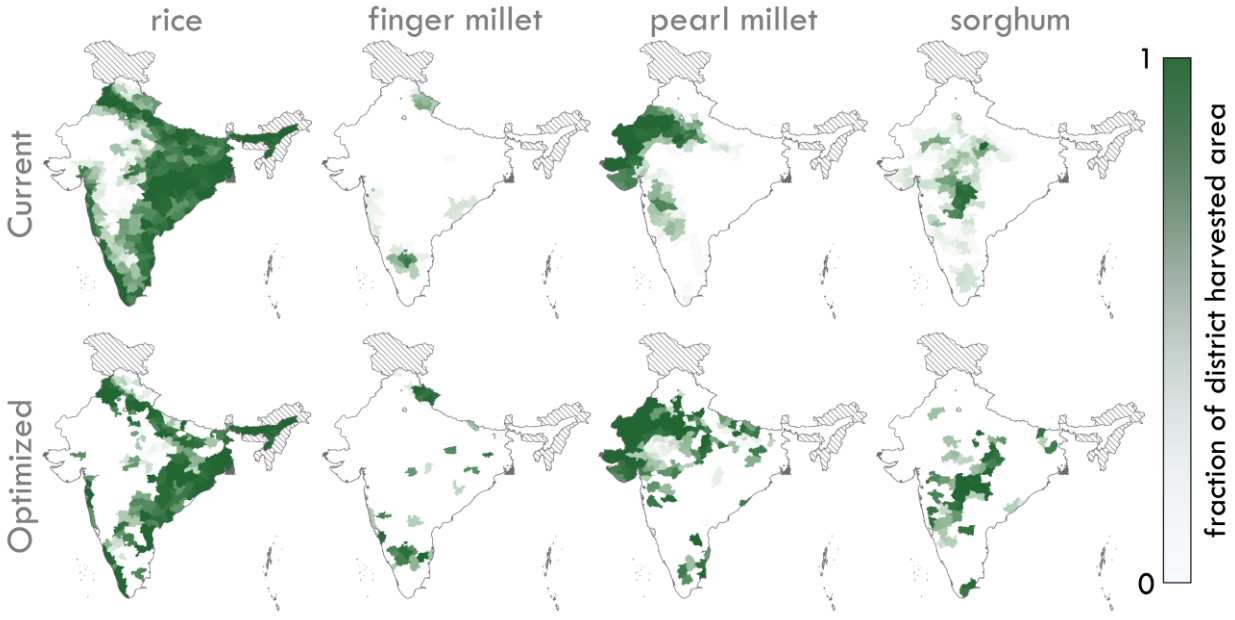

Fig. S6. Allocation of harvested area under current production and under scenario to maximize iron supply. Maps show the fraction of each district's monsoon cereal area allocated to each crop. Areas with diagonal lines indicate places with no data. Maize maps are not shown because maize production was held constant.

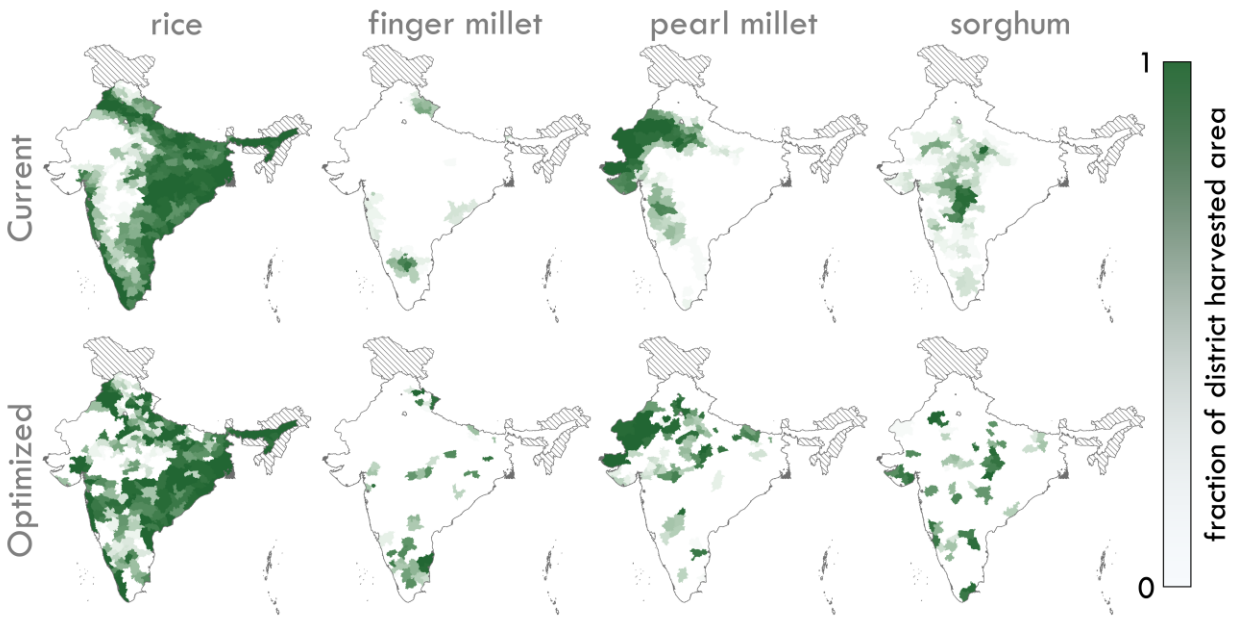

Fig. S7. Allocation of harvested area under current production and under scenario to minimize energy demand. Maps show the fraction of each district's monsoon cereal area allocated to each crop. Areas with diagonal lines indicate places with no data. Maize maps are not shown because maize production was held constant.

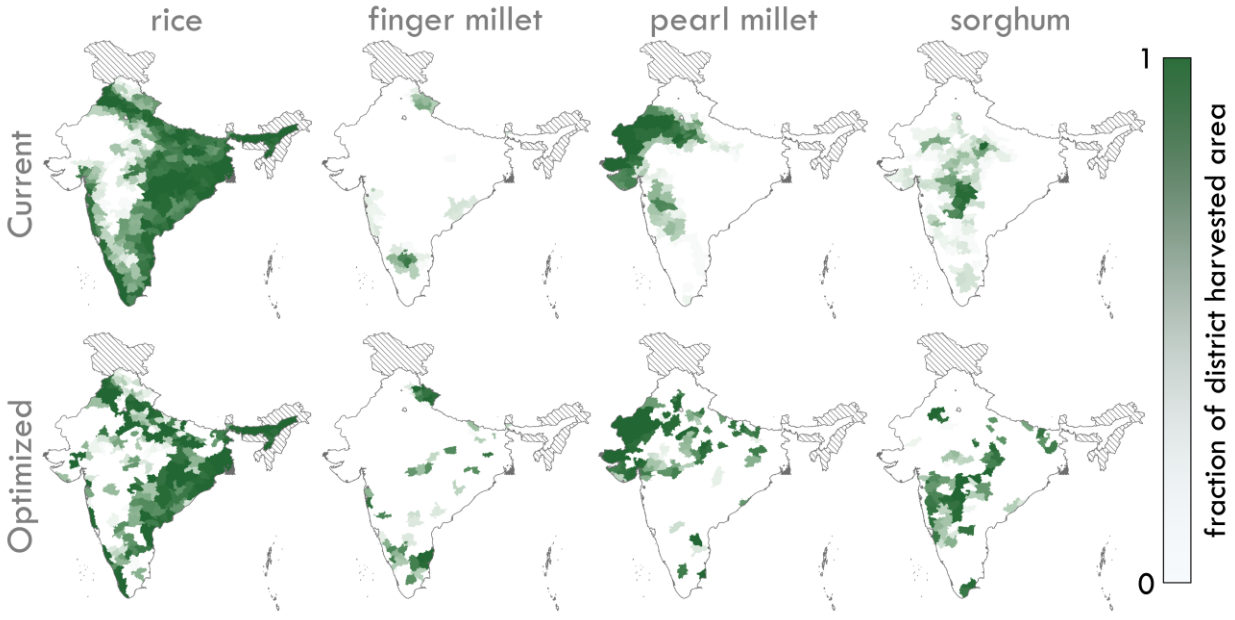

Fig. S8. Allocation of harvested area under current production and under scenario to minimize GHG emissions. Maps show the fraction of each district's monsoon cereal area allocated to each crop. Areas with diagonal lines indicate places with no data. Maize maps are not shown because maize production was held constant.

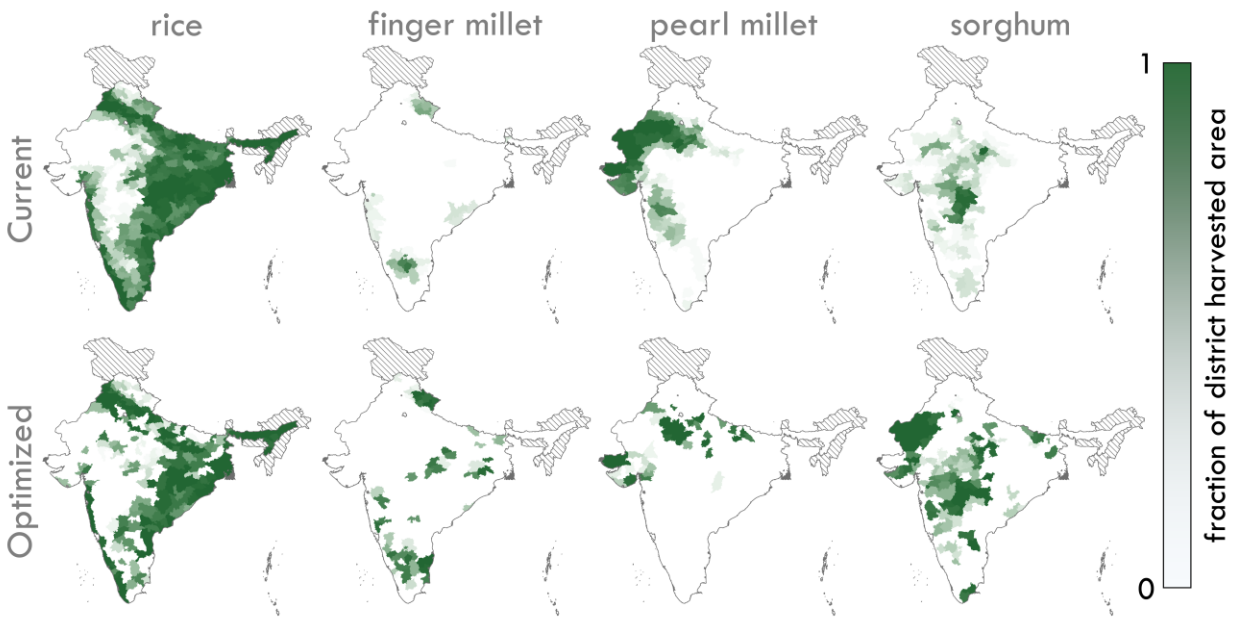

Fig. S9. Allocation of harvested area under current production and under scenario to maximize climate resilience. Maps show the fraction of each district's monsoon cereal area allocated to each crop. Areas with diagonal lines indicate places with no data. Maize maps are not shown because maize production was held constant.

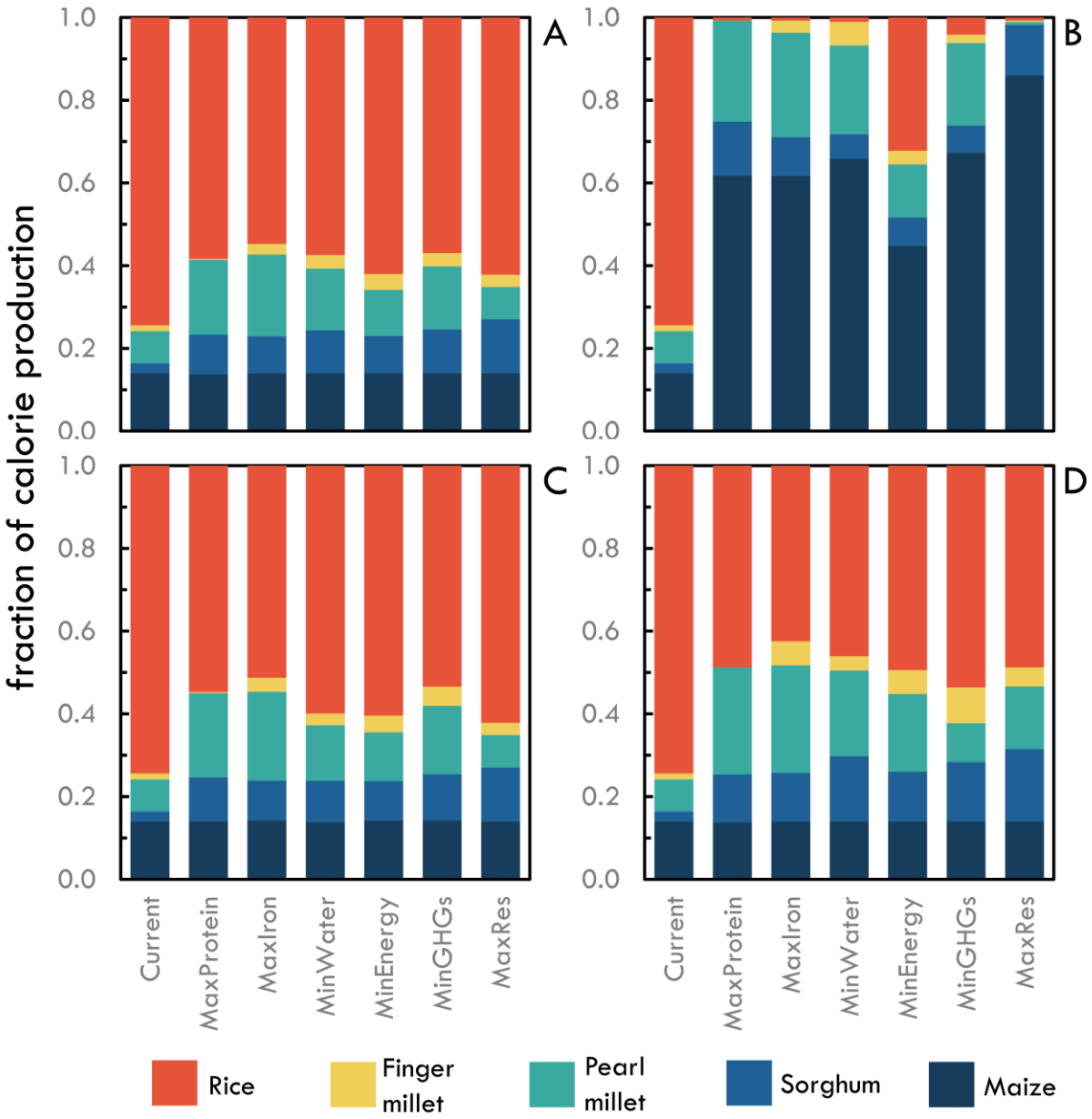

Fig. S10. Current and optimized shares of monsoon cereal production with variations on constraints. The constraints used to obtain these sets of outcomes vary from those used to obtain the main results in the following way(s): (A) Calorie supply was held constant at the national level, (B) Calorie supply was held constant at the national level, and maize harvested area could vary, (C) Calorie supply was held constant at the national level, and winter (rabi) crop harvested area could vary, and (D) Calorie supply was held constant at the national level, and states were used as the unit of optimization (instead of districts).

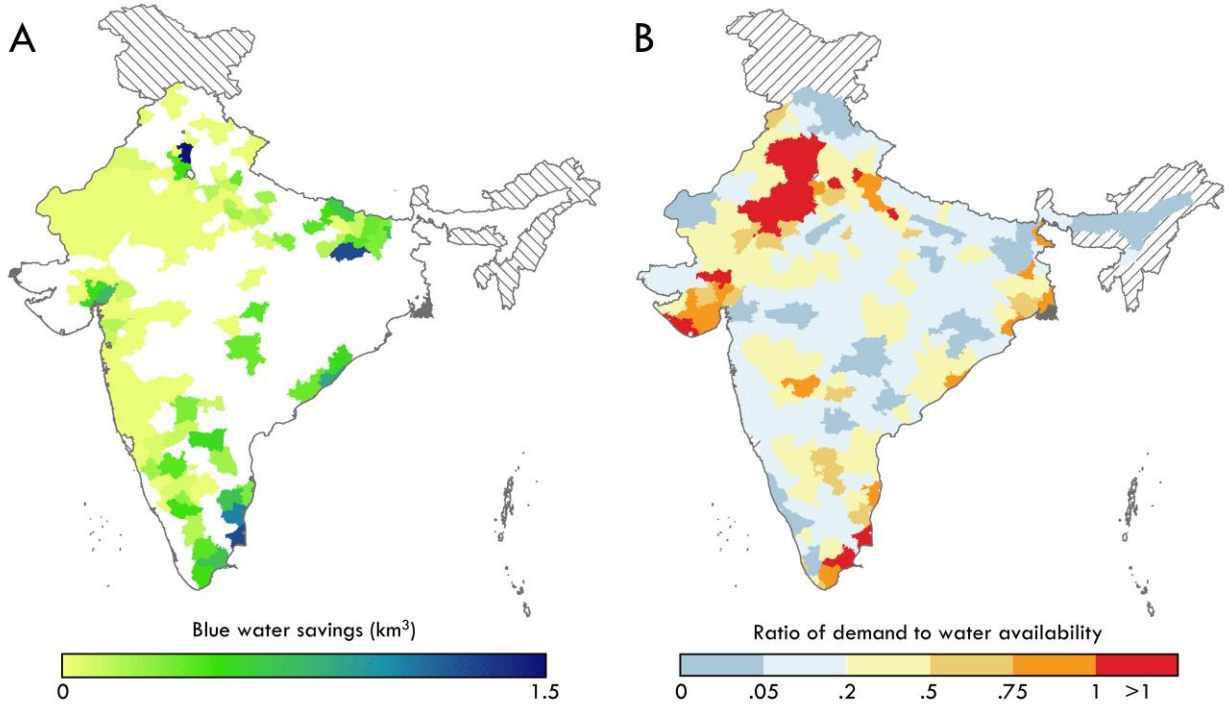

Fig. S11. Comparison of reductions in irrigation water demand to current water scarcity. (A) Map shows irrigation (blue) water savings under the optimization scenario to minimize national total water demand (i.e., MinWater). (B) Water scarcity is calculated as the ratio of current total water demand for cereal production to annual renewable freshwater availability. Any values greater than 0.2 indicate a compromised ability to meet environmental flow requirements. Water scarcity values taken from Davis et al. (2).

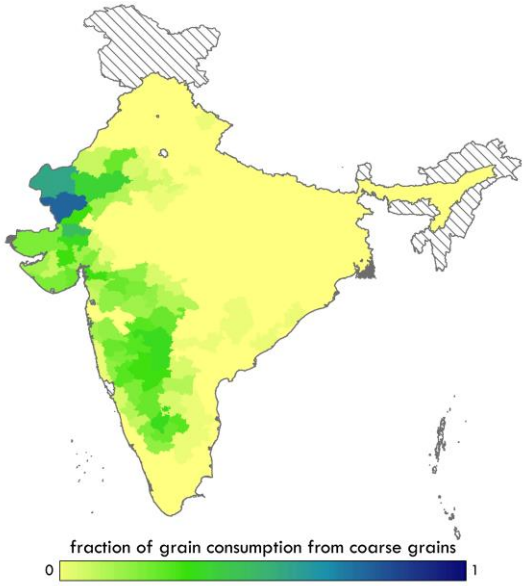

Figure S12. Contribution of coarse cereals to per capita cereal consumption. Data used here came from Davis et al. (2) who used the National Sample Survey Office household consumption dataset for the 68th round (year 2011-12).

References

1. T. Longvah, R. Ananthan, K. Bhaskarachary, K. Venkaiah. Indian Food Composition Tables 2017 (National Institute of Nutrition, Ministry of Health and Family Welfare, 2017).
2. K.F. Davis, *et al.*, Alternative cereals can improve water use and nutrient supply in India. *Sci. Adv.* **4**, eaao1108 (2018).