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Supplementary Materials for

Alternative cereals can improve water use and nutrient supply in India

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The PDF file includes:

Other Supplementary Material for this manuscript includes the following:

(available at advances.sciencemag.org/cgi/content/full/4/7/eaao1108/DC1)

Table S5 (Microsoft Excel format). Cereal consumption by crop and by district.
Table S6 (Microsoft Excel format). State-level yields of kharif crops and outcomes of rice replacement scenarios.
Table S7 (Microsoft Excel format). Crop-specific nutrient content reported in the National Institute of Nutrition's Indian Food Composition Tables.
Table S8 (Microsoft Excel format). List of crop coefficient (k_c) values disaggregated by crop, climate zone, and month.
Table S9 (Microsoft Excel format). State-level planting dates (month) for each cereal crop and growing season.
Table S10 (Microsoft Excel format). Rooting depths for rainfed and irrigated crops as reported by Siebert and Döll (*37*).

Supplementary Table captions

Table S1. CWRs by district (mm H_2O year^{-1}) for rainfed and irrigated crops. *K* denotes kharif (monsoon) season and *R* denotes rabi (winter) season.

Table S2. National production changes for kharif (monsoon) cereals under replacement scenarios.

Table S3. Cumulative water savings and changes in nutritional output from replacement scenarios. Districts were ranked based on the volume of total water savings from smallest to largest. Their cumulative water savings and associated cumulative changes in nutritional supply were then calculated including districts up to the 50th, 75th, 90th, and 100th percentile of districts based on total water savings. Negative values represent a cumulative reduction relative to current total water demand and nutritional supply. A negative value for the change in total water demand indicates a water savings (i.e., benefit), while a negative value for the change in nutritional supply indicates a reduction in supply (i.e., cost).

Table S4. Outcomes and descriptions of rice replacement scenarios. 'Required' column shows the nutrient production from cereals, based on Indian daily recommended intakes (DRIs; NIN, 2009), that would be the minimum amount required to provide recommended nutrient supply to the population of India in the year 2011. This value is the product of total minimum required nutrient production for the entire Indian diet and the fraction of nutrients provided by cereals under current consumption patterns. Descriptions of each scenario are provided at the bottom of each column. Percent difference values for each scenario and each variable are highlighted in either blue (to indicate a benefit relative to current water use and nutrient production) or red (to indicate an undesirable impact relative to current water use and nutrient production).

Table S5. Cereal consumption by crop and by district. Values (kg per capita per day) were taken from the National Sample Survey Office household consumption dataset for the 68th round (year 2011-12). For each district, the alternative kharif cereal with the highest amount of consumption is highlighted. If no other cereal considered in this study was consumed in that district, no cell is highlighted.

Table S6. State-level yields of kharif crops and outcomes of rice replacement scenarios.

Table S7. Crop-specific nutrient content reported in the National Institute of Nutrition's Indian Food Composition Tables.

Table S8. List of crop coefficient (k_c) values disaggregated by crop, climate zone, and month. *m* is equal to the planting month for a particular crop and district.

Table S9. State-level planting dates (month) for each cereal crop and growing season. *K* denotes kharif (monsoon) season and *R* denotes rabi (winter) season.

Table S10. Rooting depths for rainfed and irrigated crops as reported by Siebert and Döll (*37*).

Supplementary Figures

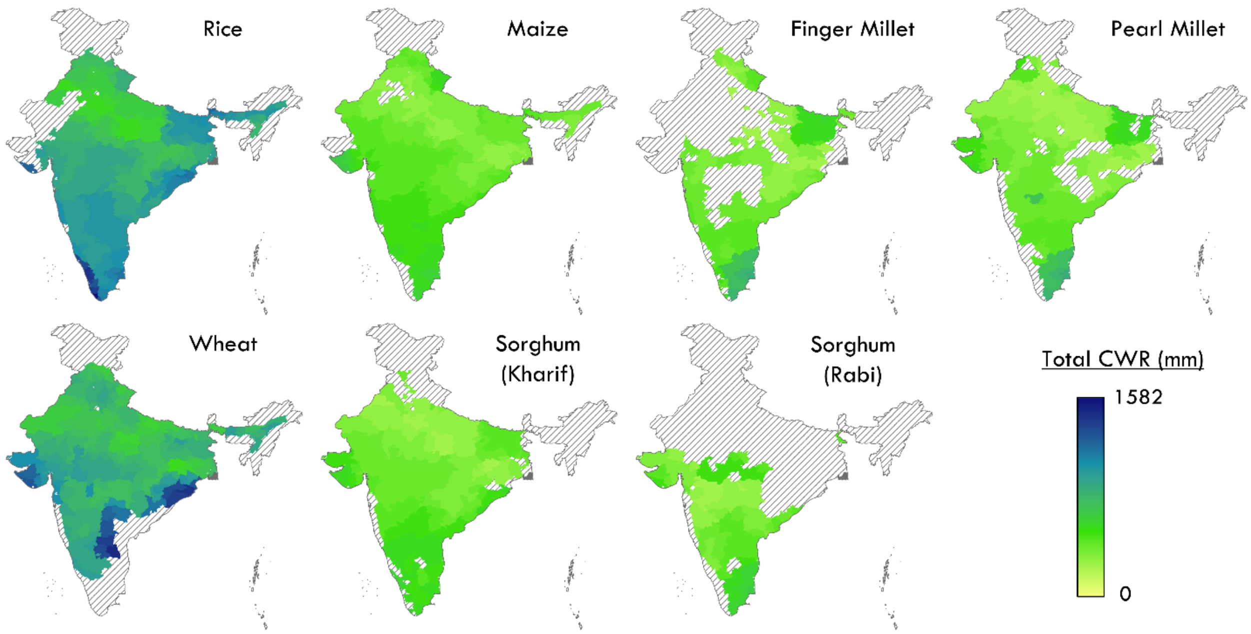

Fig. S1. Geographic distribution of total CWR (mm H_2O year^{-1}) of Indian cereals in irrigated lands. Districts in which no production occurred from 2000 through 2009 are hashed.

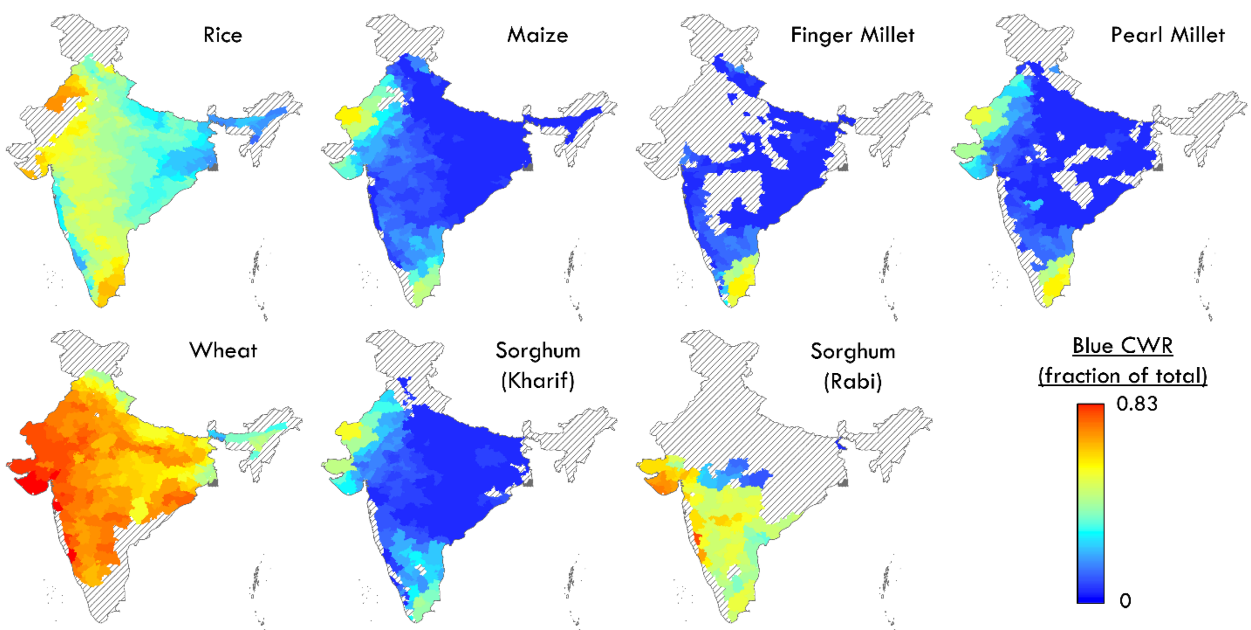

Fig. S2. Geographic distribution of the fraction of total CWR of Indian cereals in irrigated lands met by blue water.

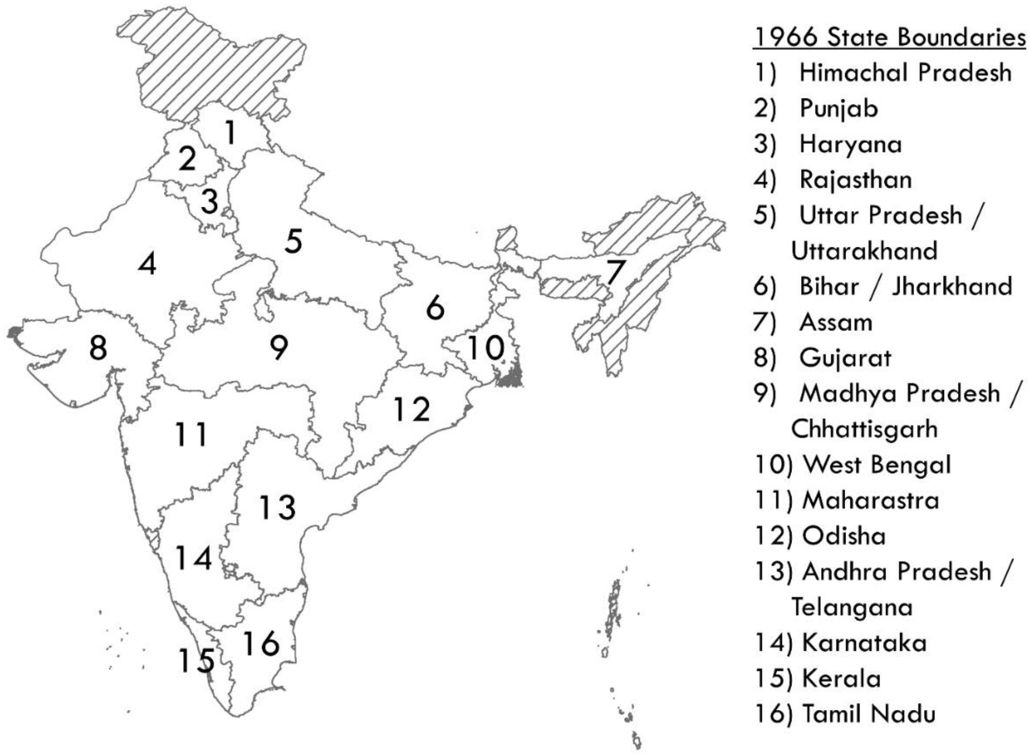

Fig. S3. Map of states based on 1966 boundaries. These boundaries are consistent with the states and districts listed in ICRISAT's VDSA dataset (*31*).

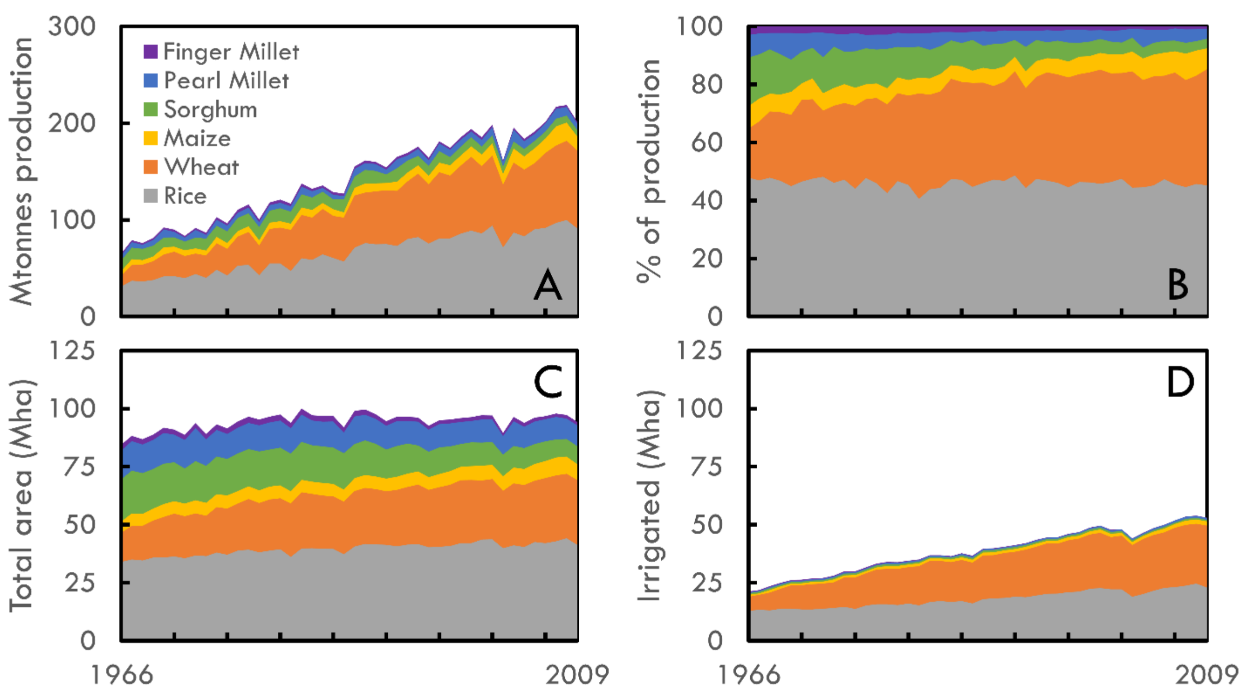

Fig. S4. Time series of Indian cereal production and extent. Data came from ICRISAT's VDSA crop production dataset (*31*) and show annual crop-specific (**A**) production, (**B**) proportion of production, (**C**) harvested area, and (**D**) irrigated area.

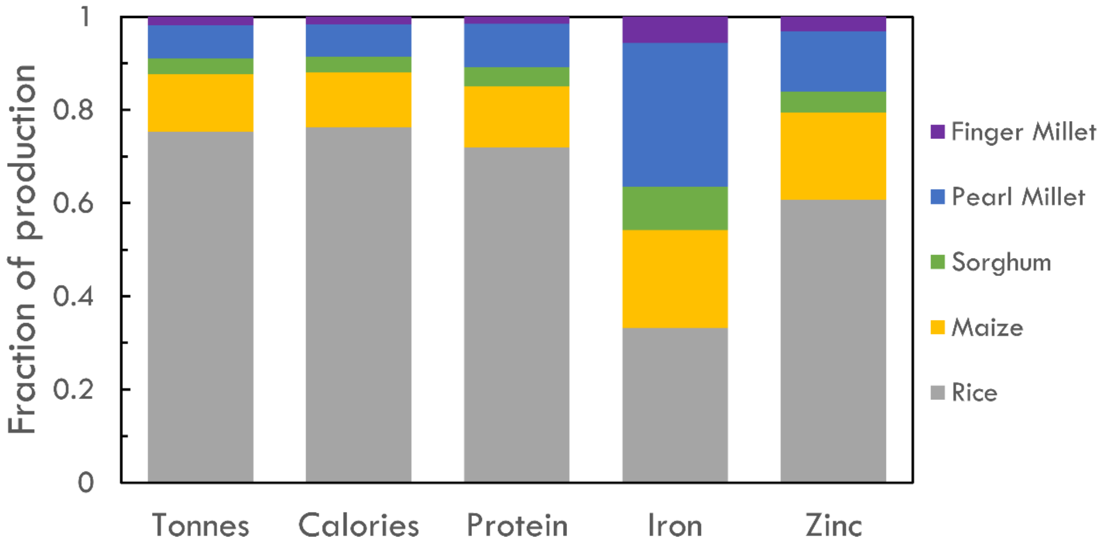

Fig. S5. Kharif production fractions by crop. Bars show the fractional contribution of each kharif cereal to nutrient production. Values are based on average production for the years 2000 through 2009. Wheat is not shown because it has no kharif production.

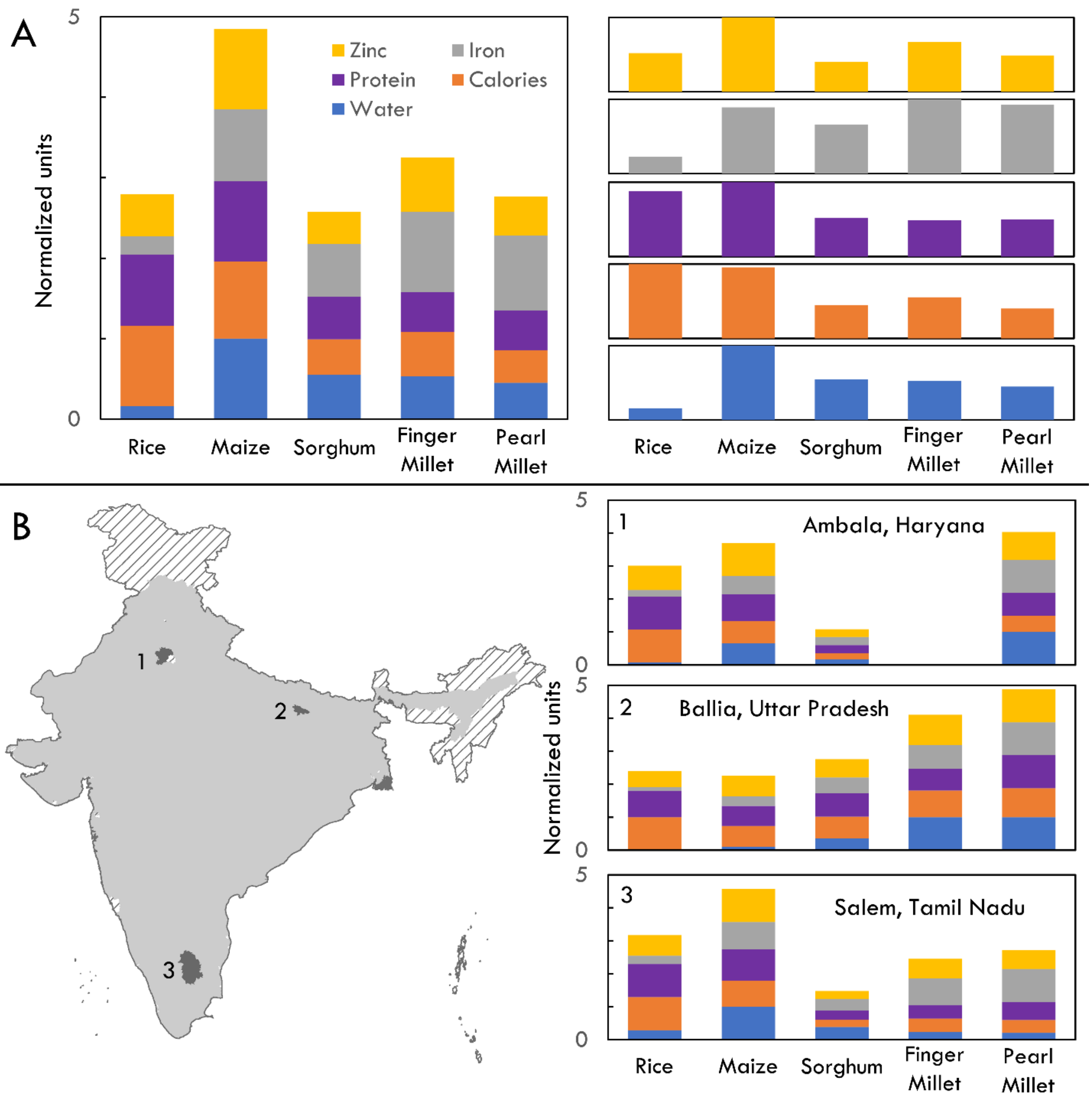

Fig. S6. Comparison of blue water use and nutrient yields of kharif (monsoon) cereals. (**A**) Values shown in this panel are national averages. Values for nutrient yields (i.e., nutrient production per hectare) are set relative to the maximum nutrient yield reported among the five kharif cereals. Values for blue water footprint were calculated as the minimum value (m^3 H_2O $tonne^{-1}$ or ha $tonne^{-1}$) among the five crops divided by the value for the crop of interest. In this way, the figure shows that the higher the value for water, the more efficient that crop is for blue water use. (**B**) Example district-level comparison to highlight the differences that occur in the relative ranking of crops as a result of yield and climate. There was no finger millet production in Ambala, Haryana.

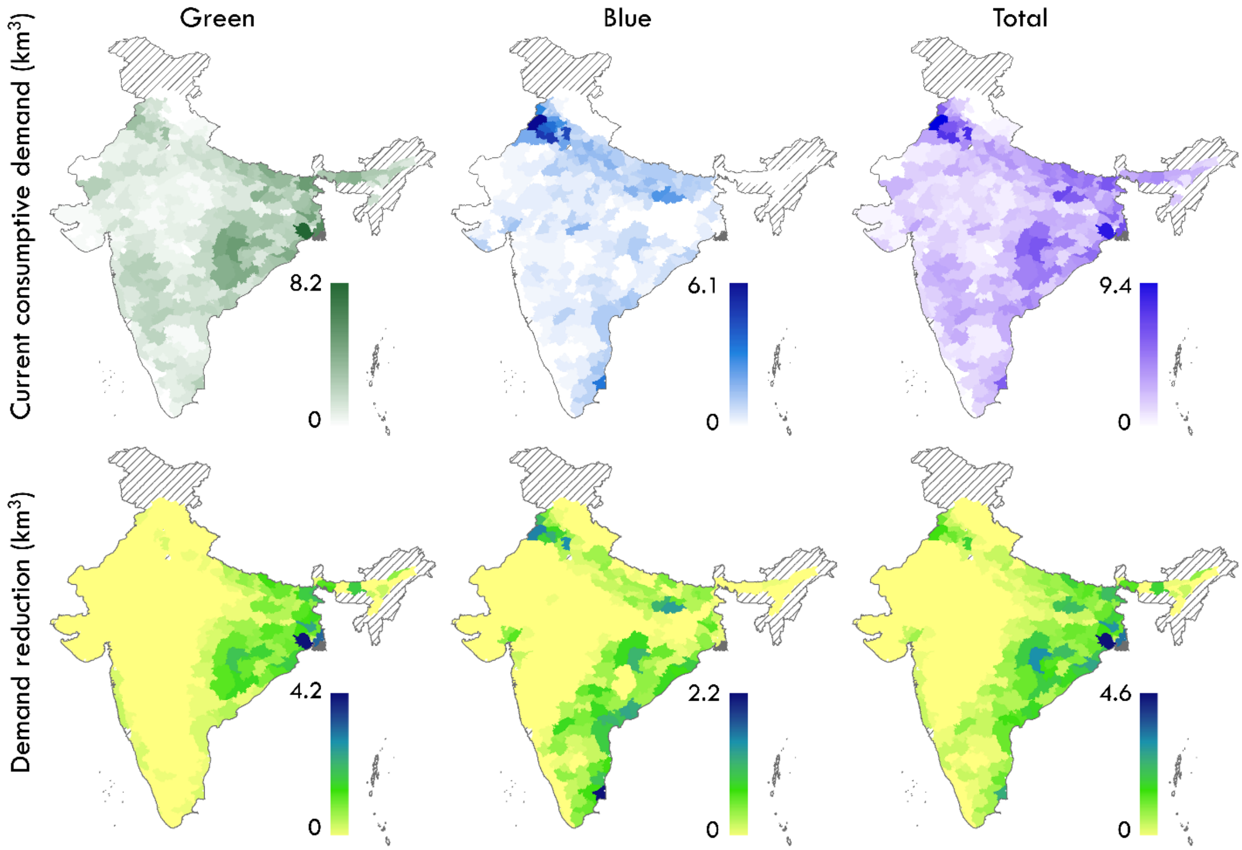

Fig. S7. District-level water savings of scenario 1 (rice replacement with the lowest total WFP cereal). The top row shows the consumptive water use under current levels of cereal production. The bottom row shows the potential water savings that would result if rice were to be replaced by the non-rice kharif alternative cereal with the lowest total water footprint in each district. For these water savings maps, a higher value represents a greater water savings relative to current consumptive use.

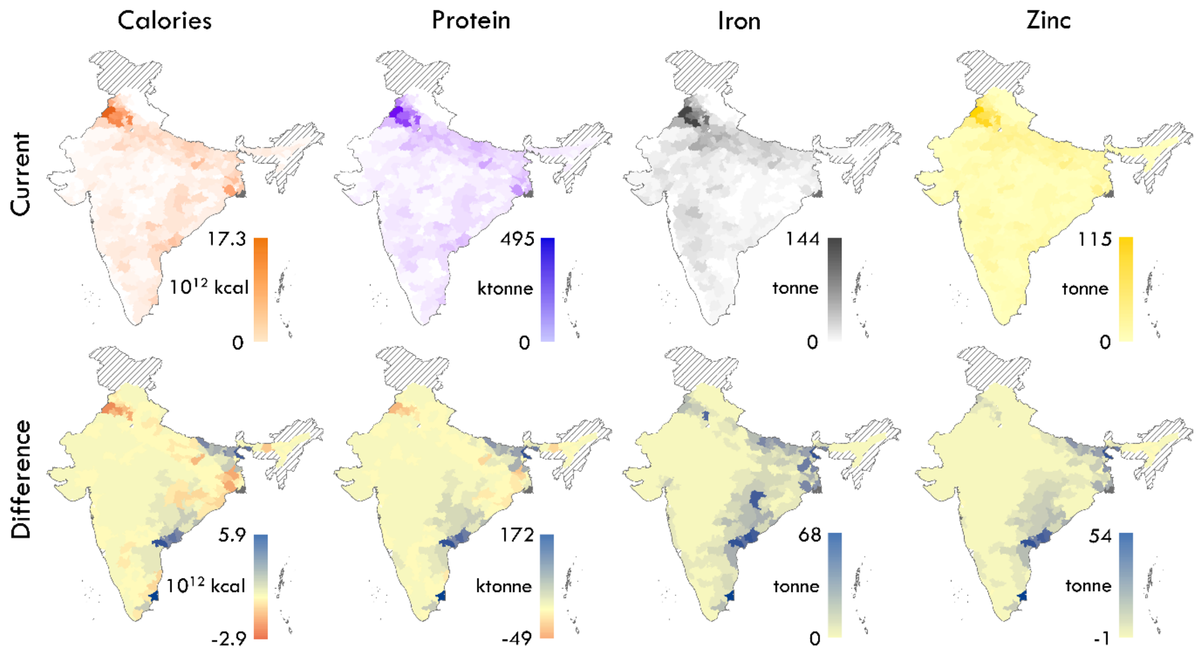

Fig. S8. Changes in nutrient production under scenario 1 (lowest total WFP). Maps in the 'Current' row show the current nutrient production from cereals by district. Maps in the 'Difference row show the difference in nutrient production between the replacement scenario and the current situation.

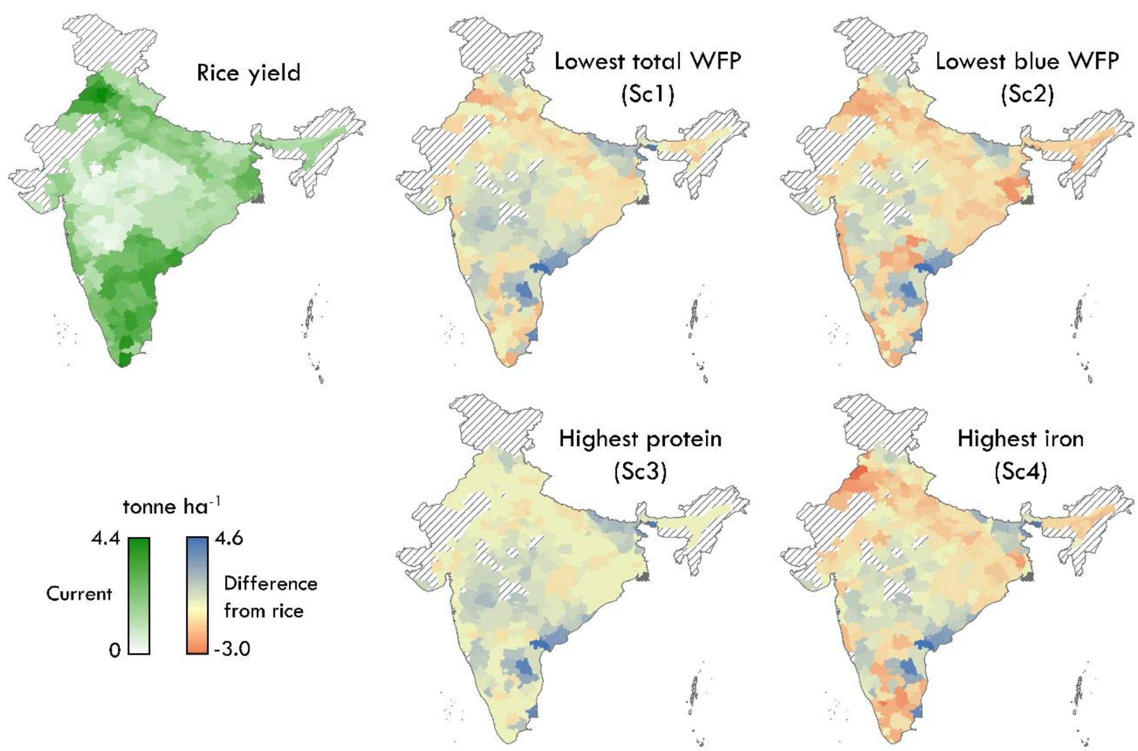

Fig. S9. Current rice yield and yield differences of replacing crop on irrigated croplands. Differences represent the yield (tonne ha^{-1}) of the replacing crop for the respective scenario minus the current (2000-09 average) rice yield for each district.

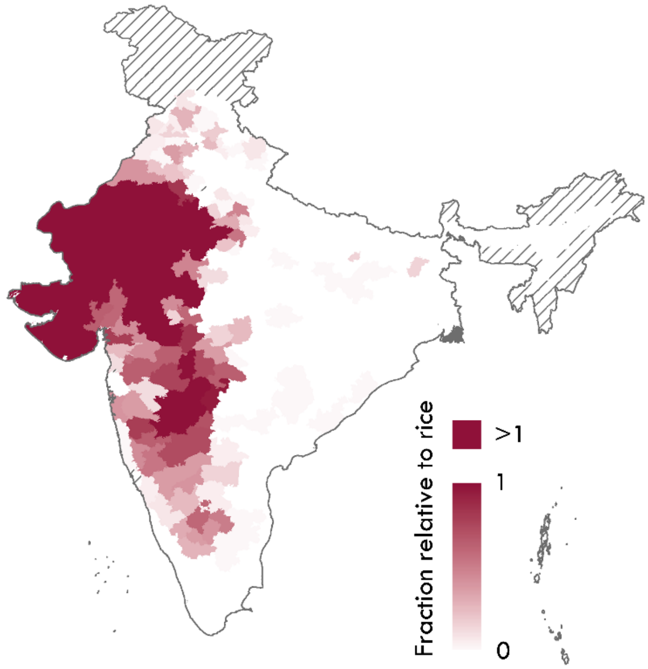

Fig. S10. Ratio of most consumed alternative kharif cereal to rice. Values used in these calculations can be found in table S5.

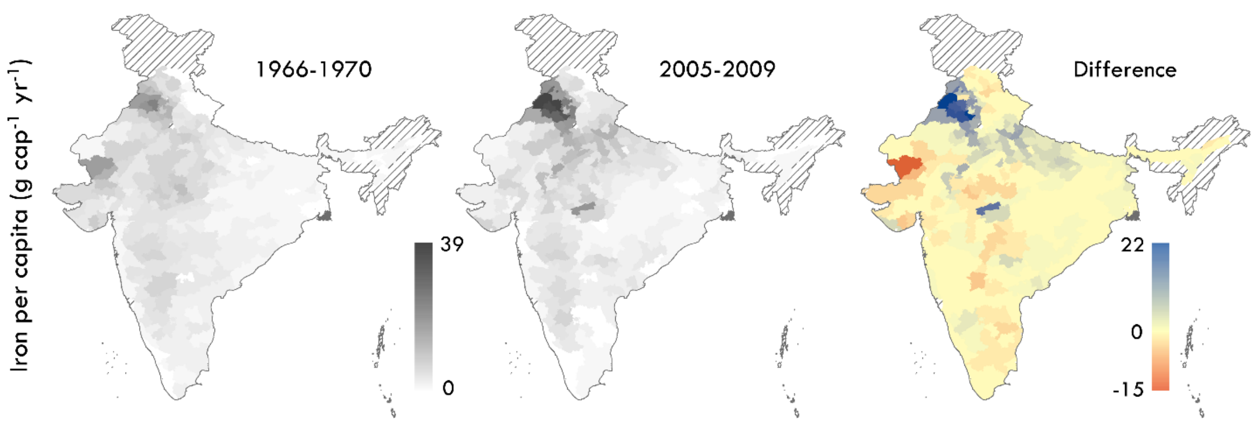

Fig. S11. Iron as an example of change in per-capita nutrient production. Changes in per capita production for each district depend on both demographic growth and changes in cereal production. Patterns of change were similar across all nutrients. Census data for the year 1971 were used for the earlier time period and year 2011 data were used for the later time period (*31*).

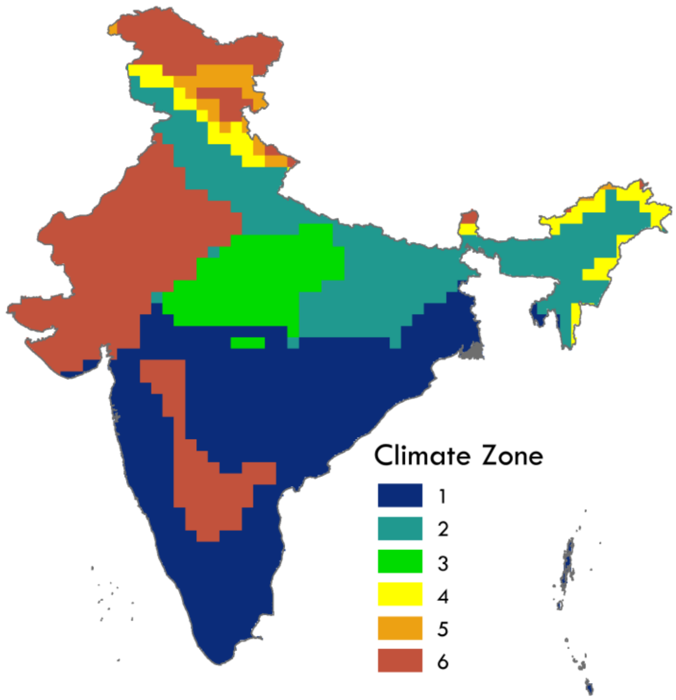

Fig. S12. Map of climate zones. Zones were developed by Mekonnen and Hoekstra (*43*) based on the main climate classifications used in Kottek et al. (*59*): 1 – Equatorial/tropics; 2 – Subtropic summer rainfall; 3 – Subtropic winter rainfall; 4 – Oceanic temperate; 5 – Continental; 6 – General.