Supplemental Materials:

Methodology

BAWCU includes two components: cropland 'blue' irrigated water and cropland 'green' effective rainfall.

$$Q_{bawcu} = Q_{cbw} + Q_{cgw} \tag{S1}$$

where Q_{bawcu} is *BAWCU* (km^3 a^{-1}) measured by 10^8 m^3 per year; Q_{cbw} is cropland blue irrigated water per year or multiple-year average (10^8 m^3 a^{-1}); Q_{cgw} is cropland 'green' effective rainfall per year or multiple-year average 10^8 m^3 a^{-1}).

Of which, Q_{cbw} is calculated as:

$$Q_{cbw} = q_{ua} \times A_{ir} \tag{S2}$$

where q_{ua} is the average amount of irrigation per unit area of the irrigated croplands (m^3 hm^{-2}); A_{ir} is the cropland areas that are actually irrigated (hm^2). q_{ua} is reported by *China Annual Water Resource Bulletin (CAWRB)* at provincial level on yearly basis; A_{ir} is reported by *China Water Statistics Yearbook* (*CWSB*), also at provincial level annually. Also, Q_{cbw} can be alternatively calculated and reconfirmed as:

$$Q_{cbw} = Q_{aww} \times p_{ir} \tag{S3}$$

where Q_{aww} is agricultural water withdrawal (10^8 m^3 a^{-1}); p_{ir} is share of irrigated water in total water withdrawal for agriculture. Q_{aww} is reported by *CAWRB* at provincial level annually; and p_{ir} is averaged over province-level statistics of ratio of irrigated water to agricultural water withdrawal. In 2017, for instance, share of irrigated water in total agricultural water withdrawal varied from minimum 62.2% to maximum 98.2%, with nationwide average 86.0%.

In comparison with cropland blue irrigated water, cropland green effective rainfall is more complicated to address, mainly due to the complicated calculations for rainfalls/snowmelts that are directly received by cropland. To circumvent such complexity, we developed a set of simple yet applicable equations to approximate the actual effective rainfall falling on cropland. The set of equations is based on following water balance principles and assumptions. When natural precipitation fell upon cropland soil, it is split into one part that runs off soil surface and another part that infiltrate into soil. Those infiltrating into soil first saturates the soil profiles and afterwards percolates downward to recharge aquifers. Those held in soil profile, which is readily available for crop transpiration and soil evaporation, are counted as green effective rainfall. Hence, the water balance equation is as follows:

$$Q_{cgw} = P_{cr} - R_{cr} - D_{cr} \tag{S4}$$

where P_{cr} is the gross precipitation falling on cropland (10^8 m^3 a^{-1}); R_{cr} is the overland flows out of the cropland (10^8 m^3 a^{-1}); D_{cr} is drainage percolating down to the aquifer (km^3). Of them, P_{cr} is calculated either by overlaying cropland maps with rainfall maps, or by a simplified assignment of total precipitation according to the share of cropland in total land areas of a region.

$$P_{cr} = P_t \times \frac{A_{cr}}{A_{tl}} \tag{S5}$$

where P_t is the precipitation falling on entire region (i.e. basin-, province- or nation-wide) (10^8 m^3 a^{-1}); A_{cr} is the area under cropland (hm^2); A_{tl} is the total land area (hm^2). A_{cr}/A_{tl} is the share of cropland in total land areas. It is assumed in *Eq.5* that precipitation falls uniformly upon each and every type of land covers/uses, i.e. forests and woods, grasslands and pastures, wetlands and barren lands, urban area and croplands etc. The precipitation falling on each type of land cover/use is proportional to its respective share of area in total land areas of a region. P_{cr} at provincial level is reported annually by *CAWRB*. Both A_{cr} and A_{tl} are reported by *China Annual Land Resources Bulletin (CALRB)*, also at province level on a yearly basis.

When dealing with cropland runoff, it is assumed that the cropland-specified coefficient of runoff equals to the basin- or region-specified coefficient of runoff available for the study basin/region. The basin/region-specified coefficient of runoff is calculated through dividing *CAWRB*-reported runoff by *CAWRB*-reported precipitation. The cropland-specified coefficients of runoff for most granary provinces can be negligible since they are so tiny values relative to precipitation due to flat topology for most croplands in major granary plains, i.e. North China Plain, Northeast Grain Belt, and Mid-and-lower-reaches Plain of Changjiang River. While on croplands with hilly topology, the coefficient of runoff has to be taken into account as follows:

$$R_{cr} = P_{cr} \times \frac{R_{tl}}{P_t} \tag{S6}$$

where R_{tl} is surface runoff reported by *CAWRB* at province level on yearly basis (mm); R_{tl}/P_t is the basin/region-specified coefficient of runoff.

The cropland percolation downwards to aquifers is derived from the calibrated/validated simulation and computation results.

$$D_{cr} = P_{cr} \times \frac{d_{cr}}{p_{cr}} \tag{S7}$$

where d_{cr} is the hydrologic-model-computed percolation to aquifer (mm); p_{cr} is the model-computed precipitation (mm); d_{cr}/p_{cr} is the model-derived cropland-specified rate of percolation or drainage at basin/region levels.

Blue water depletion rate (*BWDR*) herein defined refers primarily to the ratio of irrigated water consumed in plant transpiration and soil evaporation, along water depleted by flowing to sinks that are irrecoverable for further reuse, to water delivered to cropland.

$$BWDR = \frac{WC_{ir}}{IR_{delv}} \tag{S8}$$

where WC_{ir} is water consumption arising from irrigation (m^3 hm^{-2}); IR_{delv} is irrigation water delivered to cropland (m^3 hm^{-2}).

Green water depletion rate (GWDR) refers principally to the green water consumed by plant transpiration, soil evaporation, and depleted by flowing to sinks to the water effectively falling on cropland.

$$GWDR = \frac{WC_{gr}}{P_{eff}} \tag{S9}$$

Where WC_{gr} is water consumption arising from rainfall(m^3 hm^{-2}); P_{eff} is effective rainfall falling on cropland (m^3 hm^{-2}).

Blue water contribution rate (BWCR) is defined as the ratio of actually consumed/depleted blue water to the total water consumed/depleted water in crop biomass/yield formation.

$$BWCR = \frac{WC_{ir}}{(WC_{ir} + WC_{gr})} \tag{S10}$$

Likewise, *green water contribution rate (GWCR)* is defined as the ratio of actually consumed/depleted green water to the total water consumed/depleted in biomass/yield formation.

$$GWCR = \frac{WC_{gr}}{(WC_{ir} + WC_{gr})} \tag{S11}$$

Crop Water Productivity (*CWP*) herein is defined as *actual evapotranspiration* (*ET_a)* consumed in crops' economic yield formation.

$$CWP = \frac{OUP_c}{ET_a} \tag{S12}$$

where *CWP* is crop water productivity at basin/region level (kg m^{-3}); OUT_c is gross grain outputs at basin/region level (Mg); ET_a is actual evapotranspiration consumed in crop yield formation.

Three working steps are necessary when defining REWCU. The first step is devoted to collecting, compiling, and processing datasets required for subsequent research and modeling exercises. The second step came with characterizing and assessing nationwide and region-wide BAWCU related parameters and *CWP* by hydrological modeling approach. The third stage is to subject computing results to propose a tentative REWCU (Figure S1).

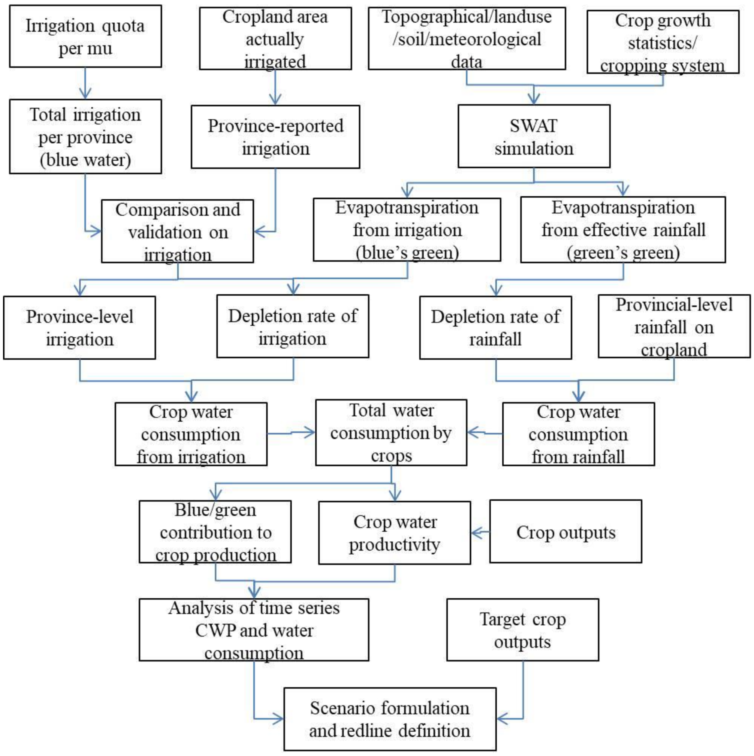

Figure S1. Roadmap of redline definition.

The detailed methodology herein developed and adopted are as follows:

1) A hydrological modeling exercises including input data preparation, model running, calibration and validation were implemented by feeding topographical (Digital Elevation Model, DEM), land cover/use, soil, and weather data into SWAT model. Nation- and region-wide (i.e. river basins and administrative provinces) simulations on water cycles (i.e. precipitation, runoff, percolation, soil water, evapotranspiration, ground water) and crop growth were done by feeding extra data into SWAT, i.e. cropping system, monitoring data on crop growth and irrigated crops, and crop zoning. The final results include the basin- and region-wide water balances, crop outputs, and consumptive use of water and crop water productivities, upon simulation and compilation on calibrated/validated simulation results.
2) The region-wide irrigation amount was obtained by multiplying *CAWRB*-reported irrigation quota and *CWSB*–reported cropland area under actual irrigation. Then the SWAT-simulated irrigation can be validated by bulletin-reported numbers. Aside from that, the depletion rate of irrigated reported by the bulletins was used in calculating the consumptive irrigation.
3) Combining simulated results and statistical data, a wide array of indicators (i.e. nation- and region-wide consumptive green and blue water, share and depletion rates of green and blue water, and crop water productivity) were obtained for time-series analysis, redline definition and policy making proposals.

More detailed methods can be referred to [15] Huang et al. (2015); [16] Huang and Li (2010a; 2010b).

Controlling water withdrawal, water use efficiency, and water quality are keys to putting the strictest water management policy into practice. The aggregated controls on water withdrawal will push water management levels upward and improve water use efficiencies. Due to variations of

IRWR in both space and time, water that may be available for human use is limited. How to meet water demands by human society and ecosystem services is a crucial question to be addressed. Key to formulating the indexing system for controlling availability and quality is to develop a robust and sound system of indicators that is founded upon biophysical endowments and socio-economic conditions both at present time and in the future. The indicator system prescribed by Comprehensive Planning on Nationwide Water Resources (CPNWR, or Nationwide Water Plan) contains three subsets: 1) aggregate withdrawal; 2) use efficiencies; 3) water quality. To 2030, nationwide gross water withdrawal should be controlled at within $7{,}000\times10^{8}$ m^3; water use per ￥10,000 ($1492 by exchange rate on early dates of 2019) of Gross Domestic Production (GDP) should be 70 m^3; water use per ￥10,000 ($1492 by exchange rate on early dates of 2019) of manufacture production values should be 40 m^3. Irrigation water use efficiency should be 0.60. Water qualities in rivers, lakes and reservoirs should in larger parts arrive at critical levels of stipulated standards.

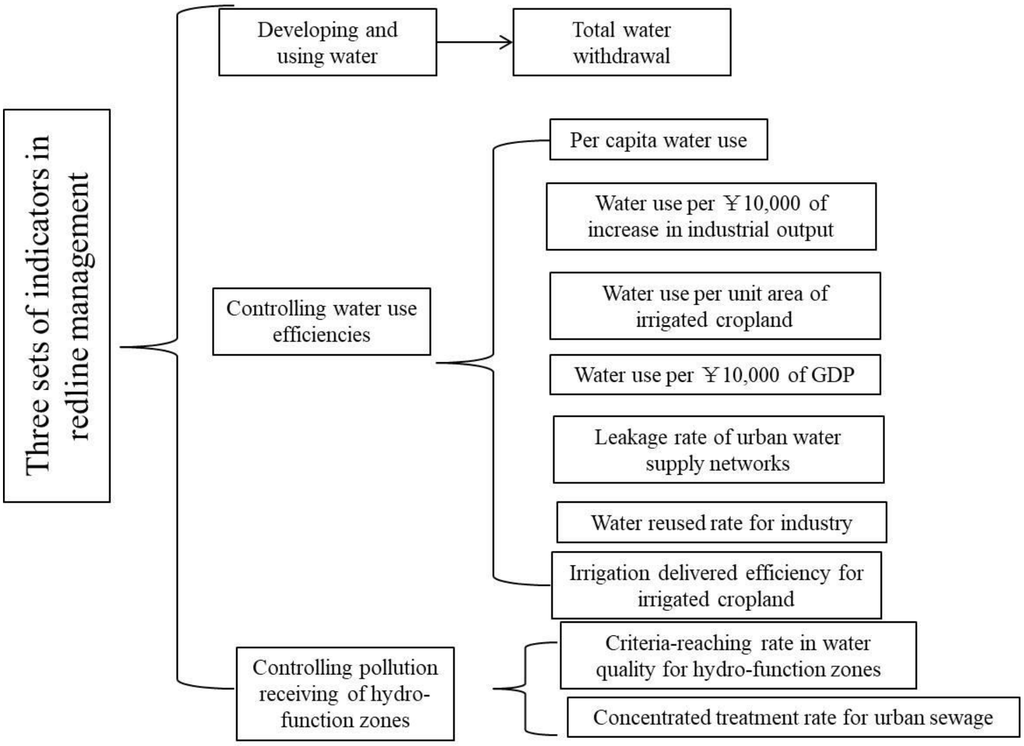

Figure 2. Three sets of indicator system for China's nationwide redline for water resource development and use, which is stipulated by China State Council and supervised by China Ministry of Water Resources.

As shown in Figure 2, three are pertinent to agriculture water use: first, the amount of irrigation per unit area of cropland; second, water use efficiency of irrigated water on cropland, and third, implicit in aggregated water withdrawal, the agricultural water withdrawal. The former two are nevertheless useful in helping define the latter one. The main principle of the redline definition is to inversely infer and compute the maximum water withdrawal for crop production based on *CWP* in the past 20-year trajectory and then projection them into 2030.

Table S1. BAWCU related indicators and CWP for major crop categories in 1998-2017.

Items	*BWCR*			*GWCR*			*BWDR*			*GWDR*		
	Max.	**Min.**	**Mean**	**Max.**	**Min.**	**Mean**	**Max.**	**Min.**	**Mean**	**Max.**	**Min.**	**Mean**
1998-2017	0.299	0.271	0.282	0.729	0.701	0.718	0.582	0.537	0.560	0.825	0.673	0.731
Projection to 2030[1]		0.282			0.718			0.624			0.856	
						CWP (kg m^{-3})						
1998-2017		**Max.**			**Min.**			**Mean**			**Projection to 2030[1]**	
Grain crops		1.257			0.952			1.087			1.481	
Vegetables		8.108			6.342			7.148			7.085	
Oil crops		0.565			0.385			0.479			0.735	
Sugar crops		3.762			2.002			2.898			6.808	
Cotton		0.241			0.190			0.230			0.260	

Footnote 1: Both BWCR and GWCR reflect medium- and long-term climatic and other biophysical variations, i.e. cropland sowing acreage and available arable land acreage. Hence, the average of recent twenty years was assumed to be project to the next couple of years to 2030. Meanwhile, both BWDR and GWDR mirror not only biophysical factors (i.e. infiltration of rainfall and irrigation, soil water retention capacity etc.), but also anthropogenic and technological factors such as water saving irrigation and rain harvesting techniques to improve irrigation and rainfall use efficiencies. Hence, a linear projection of past twenty years is assumed to project to 2030, based on annual change rate between 1998 and 2017, and baseline value of 2017. Similarly, the annual change rate of CWP in 1998–2017 is also assumed to project to 2030, based on baseline value of 2017.