Optimizing Water Transfer Megaprojects under Climate Change: A Water–Energy–Land Nexus Assessment in China

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Background

- **Inter-basin water transfers (IBWT)** are increasingly proposed as adaptation to climate-driven water scarcity, but their optimal scale depends on both future hydroclimate and energy requirements
- In China, several megaprojects are under planning, notably **the western route of the South-to-North Water Diversion (SNWD) project**

Designed vs. Optimized water transfer capacities?

WEL implications?



Designed capacities of major proposed projects considerably exceed optimized requirements

Mitigation reduces western SNWD capacity by 26%, revealing a water-energy-carbon trade-off

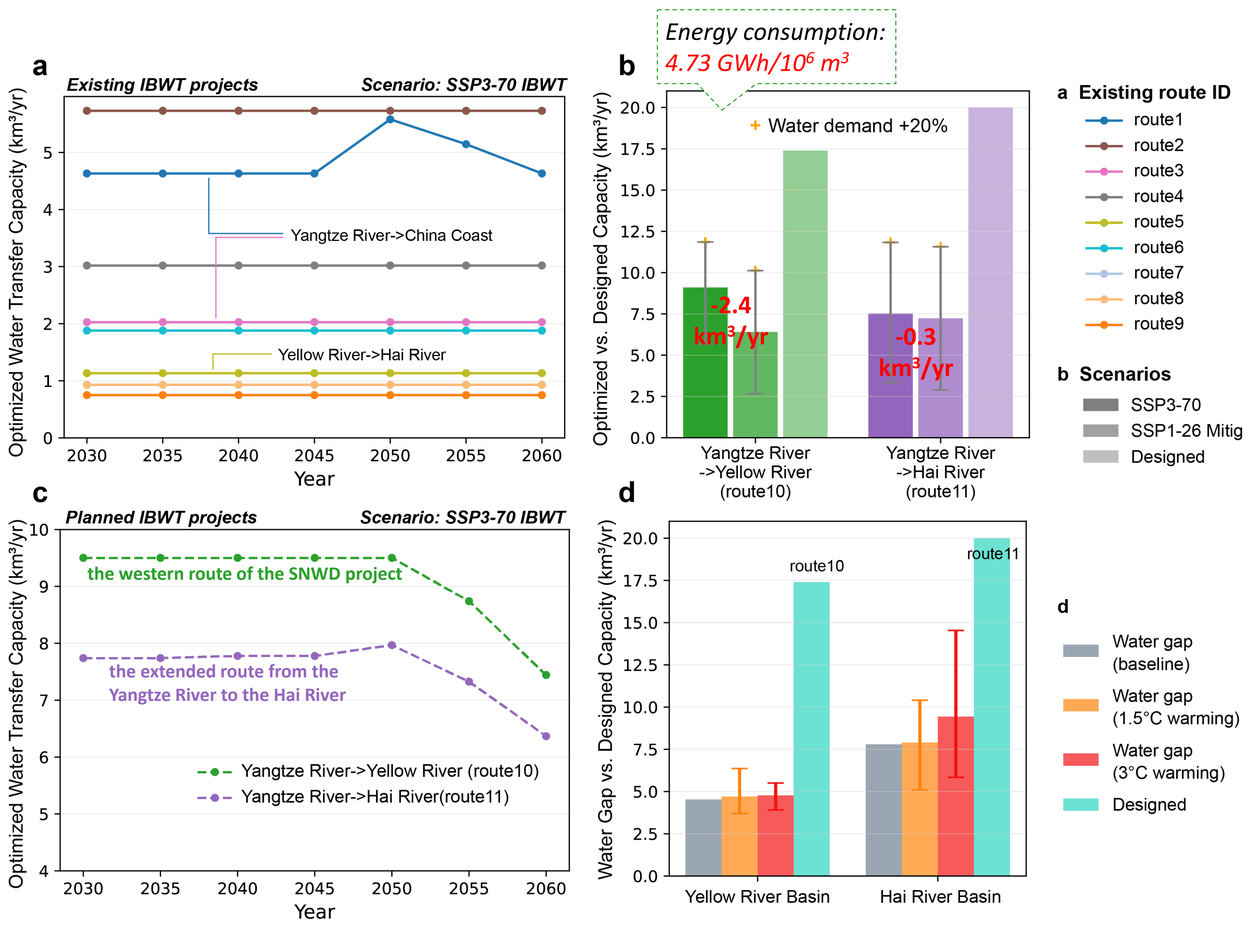


Fig. 1 Optimized IBWT capacities for (a) existing and (c) planned megaprojects. (b) Comparison of optimized mean annual water transfer capacity from 2030 to 2060 with the designed capacity. The grey error bars represent the sensitivity of the optimized capacities to water demand, showing the range obtained under a ±20% perturbation. (d) Comparison of water gap dataset with designed water transfer capacity at the recipient basin level. Error bars indicate the variability among five climate models.

Optimized IBWT deployment could reduce water scarcity by up to 76% in recipient basins

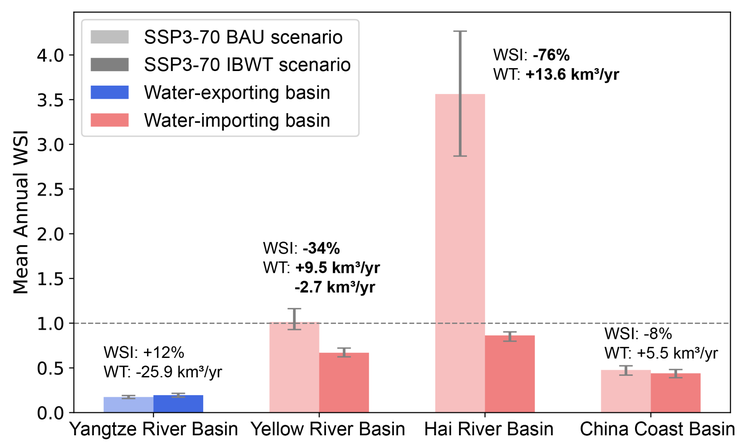


Fig. 2 Mean annual water scarcity index (WSI) during 2030–2060. Error bars indicate the minimum–maximum range of annual WSI during 2030–2060. Percentages above the bars indicate changes in mean annual WSI from BAU to IBWT, and WT denotes the corresponding change in mean annual water transfer volume.

IBWT reshapes WEL interactions by reducing desalination and groundwater withdrawals, lowering national energy consumption for water, increasing irrigation water availability and agricultural production

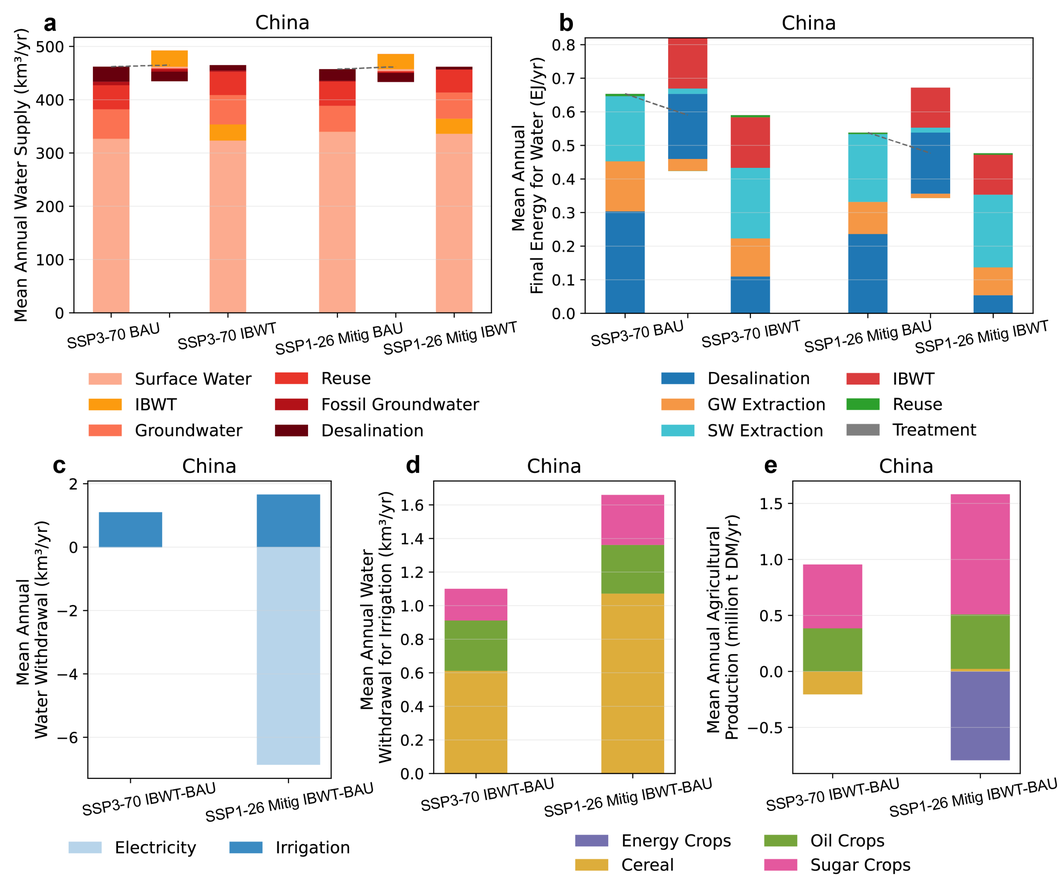


Fig. 3 Effects of IBWT on (a) water supply, (b) energy use for water supply, (c-d) sectoral water withdrawal and (d) agricultural production under SSP3-70 and SSP1-26 Mitigation during 2030-2060. (a-b) The middle floating bar shows the change induced by IBWT (IBWT − BAU). Dashed lines indicate the net change following IBWT implementation. (c-e) Changes in mean annual water withdrawal and mean annual agricultural production by crop type. Changes are calculated as the difference between the IBWT and BAU scenarios (IBWT − BAU). Positive and negative values indicate increases and decreases following IBWT implementation, respectively.

Methods

MESSAGEix-GLOBIOM → **Nexus module:** integrating water sector and climate impacts → **IBWT module:** integrating inter-basin water transfer

Scenario name	Climate impact	Carbon emission constraints	Inter-basin water transfers
SSP3-70 BAU	Severe	-	-
SSP3-70 IBWT	Severe	-	✓
SSP1-26 Mitigation BAU	Modest	✓	-
SSP1-26 Mitigation IBWT	Modest	✓	✓

** SSP1-26 Mitigation: a carbon-neutral pathway with relatively moderate climate impacts*