Appendix A: Contexts of institutional shifts

Water allocation institutions are widespread in large river basin management programs throughout the world (see *Appendix* Figure A1) [1]. This was the first basin in China for which a water resource allocation institution was created, and institutional shifts can be traced through several documents released by the Chinese government (at the national level)[2]:

- **1982**: The provinces and the Yellow River Water Conservancy Commission (YRCC) are required to develop a water resource plan for the Yellow River [2, 3].
- **1987**: Implementation of the Allocation Plan. (http://www.gov.cn/zhengce/content/2011-03/30/content_3138.htm#, last access: November 11, 2022).
- **1998**: Implementation of unified regulation. (http://www.mwr.gov.cn/ztpd/2013ztbd/2013fxkh/fxkhswcbcs/cs/flfg/201304/t20130411_433489.html, last access: November 11, 2022).
- **2008**: Provinces are asked to draw up new water resources plans for the YRB to further refine water allocations [2, 3].
- **2021**: A call for redesigning the water allocation institution (http://www.ccgp.gov.cn/cggg/zygg/gkzb/202107/t20210721_16591901.htm, last access: November 11, 2022).

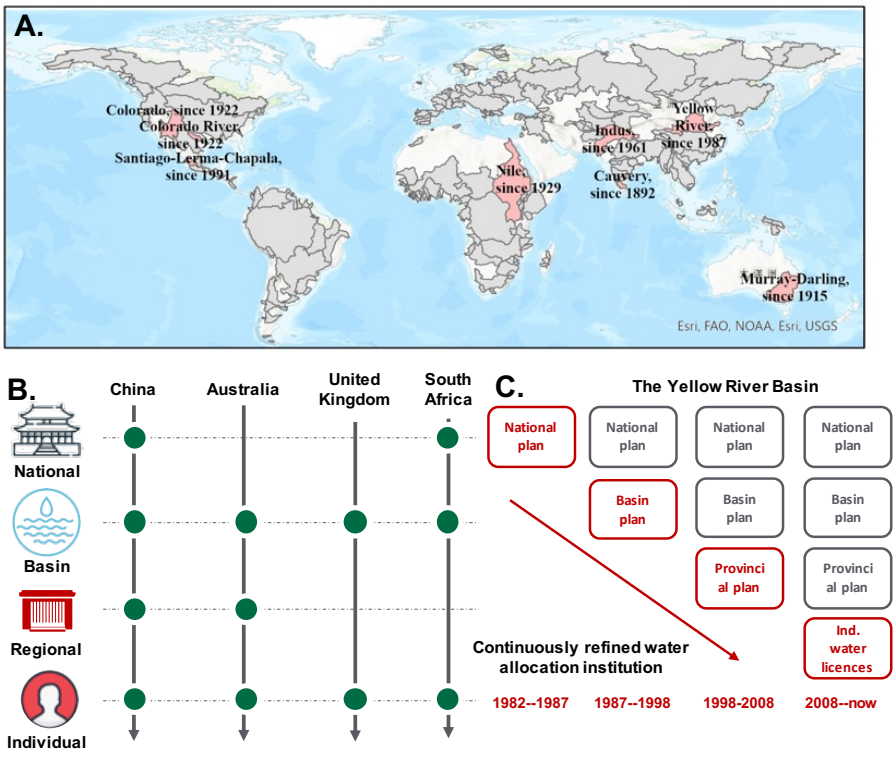
Since 1982, administrations attemptted to design a quota institution, and the 2008 document marked the maturity of the scheme (complete establishment of basin-level, provincial, and district water quotas). Between the period, two significant institutional shits can be analyzed by using the 1987 (87-WAS) and 1998 (98-UBR) documents.

The official documents in 1987 (http://www.gov.cn/zhengce/content/2011-03/30/content_3138.htm#, last access: November 11, 2022) convey the following key points:

- The policy is aimed at related provinces (or regions at the same administrative level).
- Depletion of the river is identified as the first consideration of this institution.
- Provinces are encouraged to develop their water use plans based on a quota system.
- Water in short supply is a common phenomenon in relevant provinces (regions).

The official documents in 1998 (http://www.mwr.gov.cn/ztpd/2013ztbd/2013fxkh/fxkhswcbcs/cs/flfg/201304/t20130411_433489.html, last access: November 11, 2022) convey the following key points:

- The document points out that not only provinces and autonomous regions involved in water resources management (see *Article 3*), the provinces' and regions' water use shall be declared, organized, and supervised by the YRCC (*Article 11 and Chapter III to Chapter V, and Chapter VII*).
- Creating the overall plan of water use in the upper, middle, and lower reaches is identified as the first consideration of this institution (*Article 1*).
- With the same quota as used in the 1987 policy, provinces were encouraged to further distribute their quota into lower-level administrations (see *Article 6 and Article 41*).
- They emphasize that supply is determined by total quantity, and water use should not exceed the quota proposed in 1987 (see *Article 2*).



Supplementary Figure A1 Overview of water allocation institutions. **A.** Major river basins in the world with water resource allocation systems (shaded red); the YRB first proposed a resource allocation scheme in 1987 (designed since 1983) and then changed to a unified regulation scheme in 1998 (designed in 1997 but implemented in 1998) [1]. **B.** Different water resource allocation system design patterns; the YRB is typical of a top-down system. **C.** The four periods of institutional evolution of water allocation of the YRB.

Table A1 Water quotas assigned in the 87-WAS

Items (water volume, billion m^3)	Qinghai	Sichuan	Gansu	Ningxia	Inner Mongolia	Shanxi	Shaanxi	Henan	Shandong	Jinji
Demands in water plan	35.7	0	73.5	60.5	148.9	115	60.8	111.8	84	6
Quota designed in 1983	14	0	30	40	62	43	52	58	75	0
Quota assigned in 1987	14.1	0.4	30.4	40.0	58.6	38.0	43.1	55.4	70.0	20
Average water consumption from the Yellow River from 1987-2008	12.03	0.25[a]	25.80	36.58	61.97	21.16	11.97	34.30	77.87	5.85[a]
Proportion of water from the Yellow River in total water consumption	48.12%	0.10[b]%	30.79%	58.45%	47.82%	73.55%	44.39%	24.77%	34.41%	3.11%[b]

[a]Calculated by data from 2004 to 2017.

[b]The share is too small, thus the provinces (or region) Sichuan and Jinji not to be considered in this study.

Based on the above documents, we abstracted the structural changes of SES after the two institutional changes, as shown in the main text **Figure 2C**.

References

[1] Speed, R. & Asian Development Bank. *Basin Water Allocation Planning: Principles, Procedures, and Approaches for Basin Allocation Planning* (Asian Development Bank, GIWP, UNESCO, and WWF-UK). URL http://www.adb.org/sites/default/files/pub/2013/basic-water-allocation-planning.pdf.

[2] Wang, Y. *et al.* Review of the implementation of the yellow river water allocation scheme for thirty years **41** (9), 6–19. https://doi.org/10.3969/j.issn.1000-1379.2019.09.002 .

[3] Wang, Z. & Zheng, Z. Things and current significance of the yellow river water allocation scheme in 1987 **41** (10), 109–127. https://doi.org/10.3969/j.issn.1000-1379.2019.10.019 .