Article Title

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Abstract

The abstract serves both as a general introduction to the topic and as a brief, non-technical summary of the main results and their implications. Authors are advised to check the author instructions for the journal they are submitting to for word limits and if structural elements like subheadings, citations, or equations are permitted.

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1 Introduction

Water has been described as being "at the centre of the planetary drama of the Anthropocene" [20]. It is essential, not only for earth system processes but also in supporting the economic development and continued wellbeing of human societies. Human activities stemming from our reliance on water have profoundly modified the natural water cycle, moving rivers along a trajectory towards a hydrosocial water cycle in which social and power relations dominate the nature of hydrological cycles [1, 20, 31, 41, 46]. Facing this major transformation, many of the world's big river basins (which are hot spots of civilization and economic growth) are urgently in need of new models of water governance for sustainability [7, 17, 18]. As an integral part of a proposed earth system governance framework, sustainable water governance requires a deep understanding of the complex relationships between people and water [9, 17, 49].

For water resources in populated areas, missing governance means missing sustainability [50]. A first important step in identifying transitions towards a hydrosocial water cycle is to identify the different regimes under which it occurs. According to the United Nations Development Programme (UNDP), three key dimensions of water use are decided by the water governance regime directly: "How much water can be used?" (supply), "How can different services provided by water be balanced?" (purpose), and "How can water be allocated equally and efficiently?" (allocation) [27, 37, 50]. A regime is defined as a locally stable state of a system's structure, function, and dominant controls [11]. Large and persistent changes in key system properties may lead to a loss of local stability, potentially resulting in a regime shift with impacts on system outcomes and widespread cascading effects [22, 43]. Regime shifts are both consequences and signals of substantive changes in water governance, and may lead to new challenges to sustainability.

In addition to being caused by changes in key environmental, economic, social and political variables, regime shifts in water governance can be triggered through changes in each of the three key dimensions of governance (supply, purpose, and allocation) [27, 37, 50]. First, the supply of water depends not only on weather (with worrying long-term trends in many regions, such as the loss of glaciers) but also on the demands of economic activities such as irrigation and industry; water storage can resolve some but not all of these issues [23, 42, 52]. Second, the purposes for which water is used are in need of balanced between consumptive uses (e.g., drinking and food production) and non-consumptive uses (e.g., energy production or urban services) [19, 28, 36]. Water governance can be viewed as the process of assigning weights to each of these different purposes and enforcing the resulting rules. Third, the allocation of water across the whole basin is influenced not only by regional environmental context but also by local socio-economic trends and regions' comparative economic advantages, which can be altered by changing social and political drivers [44, 47]. Despite the obvious relevance of substantive changes in any of the three dimensions of water governance, the lack of a simple but comprehensive approach to identifying changes in water governance regimes makes it difficult to achieve water governance for sustainability Figure 1.

As an informative example, we focus on the Yellow River Basin (YRB, see *Appendix* Methods S1 and Figure S1 for details). The YRB has experienced some of the most intense water use and dramatic regime shifts of any large river basin in China, giving rise to long-standing challenges for its governance. From about 550BC until half a century ago, flooding and the huge sediment loads of the Yellow River brought frequent human disasters and the constant shifts in the river's channel made it difficult for people to use its waters [32, 53]. Since the 1960s, the implementation of conservation measures, regulation reservoirs, and levee constructions have contained the issues caused by high-sediment loads [53, 58]. However, water overuse has led to drying up of the Yellow River, creating new governance challenges that have been addressed through a range of related policies (e.g., regulating water use and limiting water withdrawals) [59]. Today, given that it is still difficult to completely meet water demands and various trade-offs must be negotiated between regions and sectors, there is still a long way to go towards successful water governance [55, 56]. The YRB has been among the most rapidly-changing large river basins in the world, with myriad responses to the endless governance challenges induced by environmental, economic, social and political factors. Identifying regime shifts in water governance within the YRB can thus provide crucial insights into the world's rapidly-changing big river basins and the ways in which governance may respond to meeting challenges to their sustainability.

We first use the three key dimensions (supply, purpose and allocation) of water governance to develop an Integrated Water Governance Index (IWGI) that can detect and describe changes in water governance at a basin scale (see Figure 1 and methods). Then, by applying the index to a typical rapid-changing big river basin (the YRB), we show how the index can be used to analyse the complicated regimes of water governance and their main causes in a comprehensive but simple way. Finally, we propose a general regime transition scheme as a practical guideline for a coordinated approach to exploring the challenges faced by big river basin governance.

2 Results

2.1 Water governance regimes

With two significant breakpoints, the changes in the IWGI are divided into three periods (Figure 2A) with different slopes. The changes are contributed by different water governance dimensions (Figure 2B). In the first period (P1, 1965-1978), the IWGI increased rapidly. Water supply made the most striking positive contribution (131%), while purpose and allocation had a slight negative contribution (-11% and -20%). In the second period (P2, 1979-1994), the contributions of purpose and allocation became positive and the IWGI experienced a drop because steeply declining supply capacity played a larger negative role (dropping to -188% lower than P1). In the third period (P3, 1995-2013), as positive contributions from purpose (75%) and allocation (84%) increased further and the negative contribution of

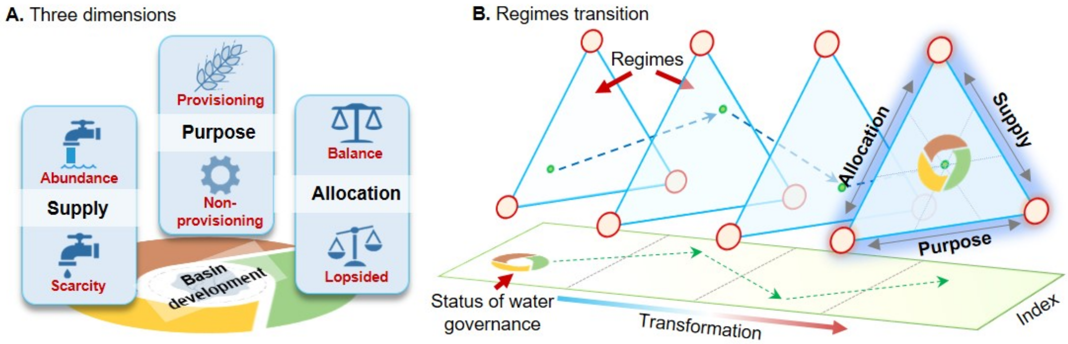

Fig. 1 A framework for understanding the relationship between transitional water governance regimes and eventual transformation to a hydrosocial cycle. A key missing element in current knowledge is an ability to detect regime shifts using a simple and comprehensive index. **A:** there are three key dimensions (supply, purpose and allocation) of water governance (see Methods for details). Each dimension has two poles (denoted in red) which indicate the two potential directions of changes along that axis: (1) "supply" shifts between scarcity and abundance. (2) "purpose" is weighted between consumptive services or non-consumptive uses. (3) "allocation" changes between balanced or lopsided. **B:** governance changes are an emergent outcome of trends across the three dimensions. Water governance status changes along a trajectory towards a hydrosocial water cycle. When abrupt change occurs, it may indicate a regime shift in water governance [1, 31, 48].

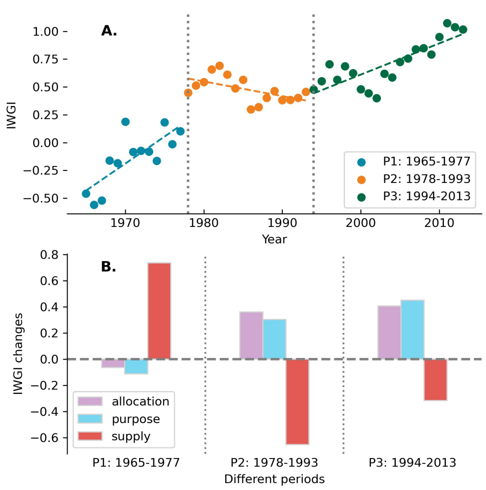

Fig. 2 Changes in the IWGI index. **A,** Change points detection. With significant change points in 1978 and 1994, the IWGI has three different periods. **B,** Contributions of each dimension to the changes of IWGI within each of the three periods. Supply, purpose and allocation were respectively the main positive contributors to P1, P2 and P3.

water supply lessened (-59%), positive growth of the IWGI returned.

Each period has a unique most striking contributor to IWGI in positive. Overall features of the three dimensions in different periods are shown in Figure 3. Throughout P1, the water governance regime was dominated by increasing supply capacities. It then experienced a shift, slowing down in increasing supply during P2, with an accompanying reverse in the contributed proportion between purpose and allocation. Finally, the contribution of all three dimensions was similar in P3 (32.91%, 31.87% and 35.21% for purpose, allocation and supply respectively), making the points cluster at the centre of the diagram. The three different periods corresponded to three distinct water governance regimes: a massive supply regime (P1: 1965-1978), a purpose-focused regime (P2: 1979-1993), and a many-sided governance regime (P3: 1994-2013).

2.2 Causes of water governance regime shifts

Digging more deeply into the underlying causes of changes in the IWGI, the expansion of irrigated area and the economic growth of industry and services were key to the change in purpose between P1 and P2. During P1, the area of irrigated agriculture in the Yellow River Basin expanded rapidly at a rate of $0.25 * 10^6 ha/yr$ (Figure4 A), and irrigation water was the dominant water use (81.56% of the total water use in 1965, and 83.17% in 1978 *SI Appendix* Fig. S3). Entering P2, however, the expansion of irrigated area stalled and industry and services gradually took off, with more water demands (Figure4 A and B), leading to a 8% reduction in the proportion of irrigation water use (*SI Appendix* S3).

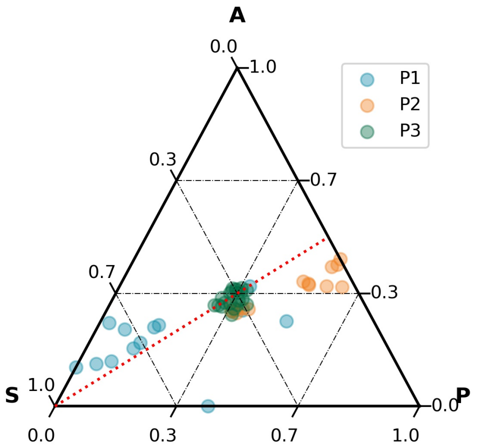

Fig. 3 Combination of contributions across three dimensions in different periods (S: supply; P: purpose; A: allocation). The closer a point is to an angle of the outside triangle, the greater the proportion of the contribution of this dimension. The red indicator line in this plot denotes a 1:1 contributions between purpose (P) and allocation (A). When the points are below this line, the contribution ratio of allocation is lower than that of function, and *vice versa.*

The efficiency of water use changed from P2 to P3. While irrigated area resumed its expansion again in P3 (Figure4A), industry and urban services assumed a stronger economic role (represented by Gross Added Values, GVA) (Figure 4B). However, because of more efficient technology and better water conservation practices (*SI Appendix* Fig. S4), both experienced significant declines in water use for unit irrigated area or unit production (Figure 4A and Figure 4B). As a result, the differences between sectors of water use were reduced while the total water consumption remained stable during P3 (*SI Appendix* Fig. S3).

Finally, environmental context, social transformation and water governance policies played roles in all three regimes. We calculated the ratios of regional and basinal water use for each reservoir (R/B ratio), with a higher ratio representing a potential role for supply rather than regulation (Figure 4C). Under the guiding ethos of "conquering nature", most of the reservoirs were built in regions with high water demands during P1, when natural water resources were relatively abundant (*SI Appendix* Fig. S5), and R/B ratios were significantly higher (Figure 4C, p¡0.01). In P2, the number of new reservoirs decreased significantly and allocation of water was rigorously controlled

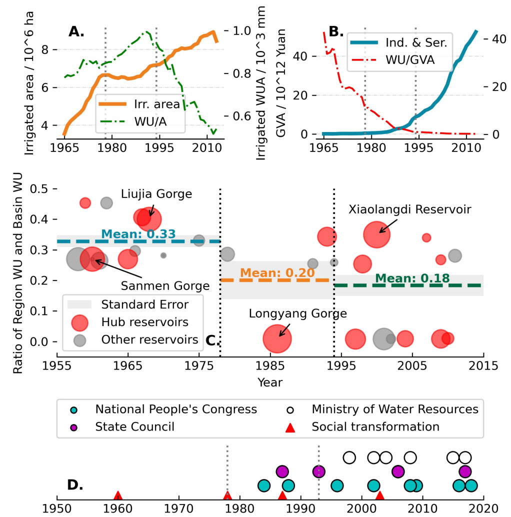

Fig. 4 Causes of water governance regime shifts in the Yellow River Basin: environmental change, economic growth and efficiency changes, social transformation, and water governance policies. **A.** Changes in total irrigated area (orange line), and water uses in per unit of area (WU/A, green dot line, see *SI Appendix* Methods S2). **B.** Changes in gross values added (GVA) of industry and services (blue line), and their water use for unit production (WU/GVA, red dot line) respectively (*SI Appendix* Methods S2). **C.** Completed time of each new reservoir and their surrounding region's water use percentages as a proportion of the basin's total water use (WU) at that time. Red circles denote hub reservoirs in the basin, which play a role in integrated basin water management. The size of each circle indicates the magnitude of its water storage capacity. Some important reservoirs include: (1) Xiaolangdi reservoir and Sanmen Reservoir, which were constructed mainly for managing sediments; and (2) Impoundments at Liujia Gorge, Longyang Gorge, which were constructed mainly for managing flood water discharge and water supply. The named reservoirs are significant for the entire basin, not only for regional development. **D.** Social transformations and national-level policies related to water governance (see *SI Appendix* Methods S1 and Table S2). In order, the four transformations are "ethos of conquer nature (since 1958)", "reform and opening-up (since 1978)", "the 87 Water Allocation Scheme (since 1987)", "environmental regulation (since 2003)" in order (see *SI Appendix* Methods S1).

by "the 87 Water Allocation Scheme", with little increase in total water storage capacity (*SI Appendix* Fig. S6). Entering P3, myriad national-level water governance policies were proposed under the guide of "environmental regulation" (Figure 4D), and the number of new reservoirs was even higher for facilitating and regulating objectives. Most of these were built in regions with lower R/B ratios (Figure 4C and *SI Appendix* Fig. S6).

3 Discussion

3.1 Water governance challenges along transition regimes

Our results show that there have been three distinct but sequential governance regimes within the YRB (Figure 3): a massive supply regime (1965-1978), a purpose-focused regime (1979-1993) and a many-sided governance regime (1994-2013). Shifts between these regimes were caused by different environmental, economic, social or political drivers (Figure 4). It is important to note that each regime occurred gradually, with multifaceted causes, as the basin moves towards a hydrosocial water cycle. The challenges were primarily economic and environmental at the beginning of the YRB's water governance trajectory and social and policy-related towards the end (Figure 5).

During the massive supply regime (1965-1978), the basin economy was mainly dependent on the agriculture and natural water resources were relatively abundant (*SI Appendix* Figure S5); water governance thus tended to supply more resources for agriculture (e.g. by construction of reservoirs and channels). Due to the limited effects of socio-economic feedbacks on this regime, water governance had few protective policies, assumed an unlimited water supply, and took little consideration of the impacts of water use on social equity and the environment [62]. Since nearly 80% of surface water was used (mainly for provisioning purposes), the Yellow River dried up during the second half of the regime (*SI Appendix* Figure S7). Ecological issues, such as wetlands shrinkage and declines in biodiversity, emerged as the drying up became more and more serious, leading a huge social-ecological crisis and a significant challenge to existing modes of water governance rigorously [57].

The start of the purpose-focused regime (1978) coincided with Chinese "reform and opening-up". This huge social transformation led to the emergence of industry and services, broke the dominance of agriculture, and resulted in higher competition for water use (Figure 4 and *SI Appendix* Fig. S8). In the face of ongoing environmental challenges and new economic challenges, the Yellow River Conservancy Commission (*SI Appendix* Methods S1) underwent a reorganization and received instructions from the Ministry of Water Resources (then called the Ministry of Water Resources and Electric Power) to resume and strengthen work on hydrology and basin management in the YRB [4]. As a result, new policies and regulations (e.g., "the 87 Water Allocation Scheme") were introduced in the YRB ahead of the rest of the country to allocate water for stopping the expansion of water consumption [54].

The next shift, to the many-sided governance regime, did not occur until a significant increase in water use efficiency in about 1993, overcame some resource limits [34]. Since socio-economic trade-offs between water-dependent regions and sectors played a more important role at this regime, water governance had to achieve efficient water allocation while balancing different purposes in the face of limited water supply [15]. For example, the water rights conversion project that has been popularized during this regime may even save regional agricultural water for industrial developments in other regions, and water transfer has been another huge project to meet water demands within the YRB [6, 61]. On the other hand, the old water policy (e.g., "the 87 Water Allocation Scheme"), which once helped the YRB resolve its environmental crisis, limited social equity and coordinated allocation under the new regime because of path dependence [54]. Many national-level water policies were proposed or adjusted under this regime, as the absence of such policies and social injustice in water use became new structural challenges for governance [29].

In general, shifts between the three governance regimes occurred sequentially during a transformation towards the hydrosocial cycle. Transition from biophysical control to social and political control of ecosystem dynamics may become increasingly widespread in social-ecological systems as increasing anthropogenic impacts gradually change the world [8, 12, 14]. Some implications of this kind of change, when accompanied by engineering solutions, have been explored in the Millennium Assessment's 'Technogarden' scenario [5]. The transition regimes identified here echo the two kinds of major water governance challenges globally (resource challenges and structural challenges, Figure 5 and *SI Appendix* Fig. S9) [40, 45]. Resource challenges, represented as water shortage and water supplying difficulties, are mainly faced by undeveloped and developing

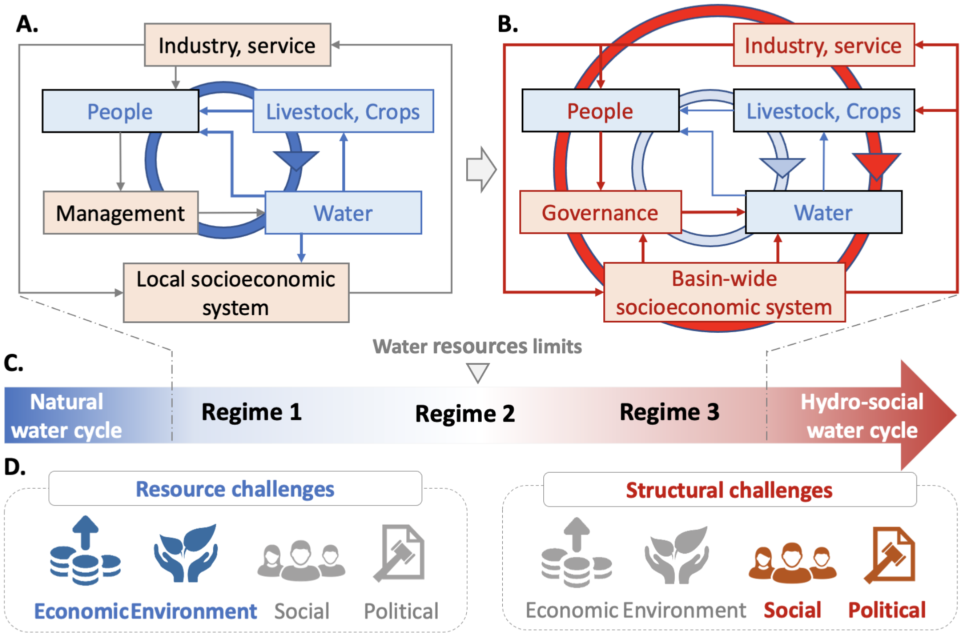

Fig. 5 Transition schema of water governance during transformation towards a hydrosocial water cycle. Blue pathways are dominated by natural water cycle while red pathways are dominated by socio-economic feedbacks. There is a transformation towards the hydrosocial water cycle where red loop increases. **A. Early phase.** As socio-economic systems develop, industry and services gradually demand increasing amounts of water; at the same time, increasing social organization and technological capacity allow people to manage water resources more intensively, including intensive intervention in the natural water cycle. **B. Late phase** With further developed and economically efficient industries and services, trade-offs between provisioning-purpose and non-provisioning water use become prominent. Rather than being determined by local socio-economic systems, water withdraws and management are scaled up to the entire basin. Thus, **C. Transformation from a natural water cycle towards the hydro-social water cycle** occurs in paralleled with a transformation towards a hydrosocial water cycle. This is generally distinguished when water resource limits are reached. The three water governance regimes seen in the YRB are identified along this transition (Regime 1: massive supply regime, Regime 2: purpose-focused regime, Regime 3: many-sided governance regime). **D. Water governance challenges** Through the transitional regimes, water governance faces primarily economic and environmental challenges in the early phase and social and policy challenges in the late phase.

basins and are highly related to economic and environmental changes [2, 19, 33]. Alternatively, highly-controlled and developed basins (especially for transboundary rivers) must mainly resolve structural challenges, such as water disputes or lack of equity, and may be in urgent need of novel flexible, efficient sociopolitical governance structures [26, 26, 44, 51]. It is typical that resource challenges and structural challenges have occurred sequentially during the transition of water governance within the YRB. Our analysis thus suggests that the initial phase of transition often leads to resource-focused challenges that result from economic, demographic and environmental change; while later phases are dominated by structural challenges relating to social and political aspects of governance. From the perspective of the core dimensions emphasized by the UNDP for water governance, our proposed schema connects governance challenges and the transformation of large river basins towards a hydrosocial water cycle.

Additional challenges are raised by the process of upscaling that occurs as river basins transition between regimes. Under the influence of economic forces, water use gradually changes from being a primarily local concern to becoming a national or international concern, with large river basins being critical sources of ecosystem services, economic development, and human wellbeing. For example, the requirement in the ecological system management of water and sediment diversion in the Xiaolangdi Dam of the Yellow River leads to rapid cutting of the downstream river, which makes it impossible for farmers to get irrigation water resources for a long time [30]. Successful navigation of water regime transitions through an upscaling process requires a corresponding upscaling in the governance regime and the creation of higher-level institutions that can regulate and manage cross-scale effects [13].

3.2 Implications and future directions

The IWGI index captures the transitional regimes of water governance in a relatively simple but comprehensive way. It is important for scientists and decision makers to recognize the changing governance challenges, because development is not a panacea for all basin issues regarding sustainability. Models and approaches developed under one regime are not necessarily useful under a different regime. For today's world, water-related challenges remains one of the major gaps in our progress towards sustainability, while development-first strategies are still a dominant guideline in many places and may be in opposition to improving governance [23, 35, 60]. Although most large river basins have shown improvements in water management technologies and water use efficiency along with development, freshwater use is still considered to be approaching planetary boundaries where human-water systems may collapse [3, 16, 25]. Overall, there are probably two main reasons for this apparent failure of governance. First, significant improvement in agricultural irrigation efficiency is usually accompanied by a re-expansion of irrigated area, resulting in an unabated trend of water resources stress (the paradox of efficiency) [21]. Second, without successful governance, complicated governance structures dominated by hydrosocial water cycles may result in less flexible water use and undermine the resilience of social-ecological systems at a basin scale [24, 31, 42]. From these perspectives, we need better and more comprehensive strategies to address governance challenges because the core problems are complex and difficult to manage [9, 10, 38, 49]. A deeper understanding of governance that incorporates ideas of non-liner change, regimes, and transitions should help to shift the focus of governance towards maintaining the resilience of the basin's social-ecological system and improving its sustainability.

4 Conclusion

5 Methods

The aim of this analysis was to develop a transparent and easily replicable approach to identifying water governance regimes and regime shifts; thus, it is not intended to provide a comprehensive model of social-ecological water dynamics. We constructed the Integrated Water Governance Index (IWGI) based on three dimensions (supply, purpose, allocation, see Figure 1) selected a priori and identified the changes in periods of the index over time using change point detection. Each dimension is reflected by an independent indicator after normalization, and water governance regimes were characterized by the combination of impacts along each dimension at different time periods. The contribution to changes of IWGI index along with each main indicator were also decomposed and calculated separately for each regime period.

5.1 Integrated Water Governance Index (IWGI)

Our Integrated Water Governance Index offers an accessible and operational way of measuring regime changes based on the transparent underlying assumptions that water resources governance system is closely related to a transformation towards a hydrosocial water cycle in the three dimensions below (see Figure 1 and SI 322 Appendix Methods S4 for details) [1, 31, 48].

- **Supply**(S): Socio-economic dominance may lead to further demands on the water supply because of increasing water withdrawals. However, since effective water governance may boost supply capacities to meet water demands by technical solutions in the process of development:
$$Transformation \propto S^{-1} \tag{1}$$
- **Priority**(P): Transformation is usually accompanied by a change of purpose in water governance towards socio-economic services (usually towards non-provisioning purposes), because of higher returns:
$$Transformation \propto P \tag{2}$$

- **Allocation(A)**: Transformation usually leads to more complicated structures in water allocation, as a result of division and cooperation between regions and sectors because of environmental context and economic comparative advantages:

$$Transformation \propto A \tag{3}$$

We combined these three dimensions into a single integrated index, keeping their positive or negative relationship with the transformation towards a hydrosocial water cycle:

$$Transformation \propto P * A * S^{-1} \tag{4}$$

To effectively represent the three dimensions, we selected an appropriate indicator (I_x, $x = S$, P or A corresponding to supply, purpose, and allocation respectively) for each dimension. Then, the above equation was transformed into a natural logarithm to facilitate calculation:

$$Transformation \propto ln(I_S) + ln(I_P) - ln(I_A) \tag{5}$$

Assuming they have equal weights, the Integrated Water Governance Index (IWGI) is:

$$IWGI = I'_S + I'_P - I'_A \tag{6}$$

where I'_x is a normalization of log-transformed indicator I_x for a certain dimension:

$$I'_x = normalize(ln(I_x)) \tag{7}$$

Normalization

We tested different normalization methods, and they made no difference in change points detection (see *SI Appendix* Methods S5. Sensitivity analysis). We performed min-max normalization using the formulation below:

$$normalize(X) = (X - X_{min})/(X_{max} - X_{min}) \tag{8}$$

Indicator of supply

We used the scarcity-flexibility-variability (SFV) water stress index proposed in Qin et al., 2019 to evaluate water supply capacities (SFV_i) as the indicator in a certain region i [42]. This metric takes into account management measures (such as the construction of reservoirs) and the impact of changes in the industrial structure of water use on the evaluation of water scarcity (see *SI Appendix* Methods S4 for details). For the whole YRB, the indicator of supply capacity I_S is the average of all regions' SFV-index:

$$I_S = \frac{1}{4} * \sum_{i=1}^{4} SFV_i \tag{9}$$

Where SFV_i is the SFV-index for region i, and $i = 1$ to 4 refers SR, UR, MR, and DR (see *SI Appendix* Methods S1 Definition of study area).

Indicator of purpose

To quantify purpose I_P, we used Non-Provisioning purpose Shares (NPS) of water use as an indicator. While provisioning purpose water use (WU_{pro}) includes domestic, irrigated and livestock water uses, non-provisioning purpose water use ($WU_{non-pro}$) includes industrial and urban services water uses. We calculated the NPS as:

$$NPS_i = \frac{WU_{non-pro,i}}{WU_{pro,i} + WU_{non-pro,i}} \tag{10}$$

Where i refers a certain region, or the whole basin, i.e:

$$I_P = NPS_{basin} \tag{11}$$

Indicator of allocations

To describe allocations I_C, we designed an indicator based on information entropy, called Allocation Entropy Metric (AEM), AEM measures the degree of evenness of water allocation (see *SI Appendix* Methods S4). Our indicator I_C was intended to reflect the idea that with the development of society, water resources allocation becomes more balanced among regions and generally meets the needs of different sectors, but different regions have a trend of division of labour among various sectors (with larger gaps):

$$I_C = \frac{AEM_r * AEM_s}{AEM_{rs}} \tag{12}$$

where AEM_r and AEM_s are Allocation Entropy Metric in different regions and different sectors. AEM_{rs} describes differences between sectors in a certain region relative to the whole basin (see *SI Appendix* Methods S4).

5.2 Change points detection

With no assumptions about the distribution of the data, the Pettitt (1979) approach of change-point detection is commonly applied to detect a single change-point in hydrological time series with continuous data [39]. It tests $H0$: The variables follow one or more distributions that have the same location parameter (no change), against the alternative: a change point exists. The non-parametric statistic is defined as:

$$K_t = max\mathsf{U\_–t,\ T''} \tag{13}$$

Where:

$$U_{t,T} = \sum_{i=1}^{t} \sum_{j=t+1}^{T} sgn(X_i - X_j) \tag{14}$$

The change-point of the series is located at K_T, provided that the statistic is significant. We used 0.001 as the threshold p-value (see *SI Appendix* Methods S5 for Sensitivity analysis), meaning that the probability of a statistically significant change-point judgment being valid was more than 99.9%. Since this method can only return one significant change point, we repeated it until all significant change points were detected.

5.3 Contribution decomposition

We decomposed the amount of variation in each index at different periods to quantify each influence's contribution to the index. Using the Integrated Water Resources governance (IWGI) Index as an example, its value is influenced by normalized indicators in three dimensions: stress (I'_S), purpose (I'_P) and allocation (I'_C). We can calculate their differences between two certain years (y_2 and y_1, $y_2 > y_1$) by:

$$\Delta IWGI = (I'_{P_{y_2}} + I'_{C_{y_2}} - I'_{S_{y_2}}) - (I'_{P_{y_1}} + I'_{C_{y_1}} - I'_{S_{y_1}}) \tag{15}$$

$$= (I'_{P_{y_2}} - I'_{P_{y_1}}) + (I'_{C_{y_2}} - I'_{C_{y_1}}) + (I'_{S_{y_1}} - I'_{S_{y_2}}) \tag{16}$$

$$= \Delta I'_P + \Delta I'_C + (-\Delta I'_S) \tag{17}$$

Then, the contribution of dimension x to IWGI's changes can be referred to as:

$$Contribution_x = \frac{\Delta I'_x}{|\Delta IWGI|} \tag{18}$$

5.4 Datasets

In order to calculate IWGI, we need to calculate multiple indicators and sub-indicators. All the datasets used are listed in the *SI Appendix* table S1. A detailed description of the data is provided in the supplementary materials *SI Appendix* Methods S2.

Supplementary information. If your article has accompanying supplementary file/s please state so here.

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Declarations

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- Conflict of interest/Competing interests (check journal-specific guidelines for which heading to use)
- Ethics approval
- Consent to participate
- Consent for publication
- Availability of data and materials
- Code availability
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Appendix A Section title of first appendix

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