Water resource utilization regimes at a basin scale: transition framework and development traps

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The importance of water resources to human society, the impact of humans on water resources, the relationship between humans and... A complex human-water relationship is gradually being established between water resources. And resulted in water utilization regime. This helps to identify and understand the traps in the development of river basins, thus providing a theoretical basis for integrated water resources management and development in a coordinated way.

Water resource management | Human-water relationship | Water scarcity | Sustainable development

Water, at the centre of the planetary drama of the Anthropocene, is not only essential for myriad Earth system processes, but also a key resource supporting development of human societies in various aspects (1). At the same time, however, human's modification has profoundly influenced water processes and related changes may lead to adverse transitions in functions of human-water systems, along with various development traps. Facing major challenges of the Anthropocene, many of the world's big river basins are also centres of economy and civilization and urgently in need for integrated water resources management toward sustainability. (2) Therefore, understanding the complex relationship between human societies and water resources utilization provides underlying supports to development in a coordinated way, at a basin scale.

Regime is a general term of systems structure and function and one of the most explanatory perspectives when analysis interactions within a coupling system, like human and water. Since widespread fluctuating disturbances in social development and natural water resources were out of consideration, water utilization regime only will be driven shifting when reorganizations occurred and the tipping points reached. As many large river basins had all experienced phases of accelerated water exploitation, over-exploitation of water resource, and integrated water management, it is a reasonable assumption that existence of a transitional water utilization regime corresponds to development of societies. Understanding the transitional nature of water resource regimes, therefore, can help to diagnosis and predict development traps, which is crucial for integrated management and coordinated development at a basin scale regard to sustainability. Despite pervasive and important as it is, there is lacking of effective method to detect the water utilization regimes and their shifts, with much fewer attempts to develop formal models of its transitions as well.

The key to analysis water utilization regimes is to understand the interactions between human societies and water resources, which have been depicted from different dimensions, as an ancient but evergreen topic. Firstly, the most widespread concern is the rising stresses on human societies with regard to water resources. Even though the stocks of water in increasing artificial reservoirs are helpful to water resources availability, highly stressed basins still characterized by high water consumption intensities and a major constraint to socio-economic development, driven by a significant increase in water extractions and a larger share of inflexible water utilization during the last century. (3–5) Secondly, as the need of industrial and ecological developments, tendentiousness of water utilization changed with. Despite a major water utilization of agricultural irrigation dominating most of the river basins, there are significant growths and preferential tendentiousness in the economy profits and water consumption regarding industry, leading a high potential for conflict between the industrial and agricultural sectors. (6, 7) Thirdly, since water availability and utilization are inherently regional concerns, patterns of also play an important role. Although only 10% of available water is withdrawn on global average, about 30% of population live in highly water-stressed areas, where dominated sections regarding water utilization are various. (8, 9) In addition, human activities are still changing this pattern, since positive impacts caused by human interventions mostly occur in upper regions whereas aggravated water resources downstream, in many basins around the world. (10) Although existing researches have evaluated the aspects of water resource utilization from these different dimensions, we still cannot obtain a coherent understanding of regime regard to social development and water utilization, without integrating them.

Here, by integrating three above mentioned dimensions of water utilization, we develop an Integrated Water Resources Utilization (IWRU) Index at a basin scale to give a sketch of

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Shuai Wang and Bojie Fu designed this research, Shuang Song performed the research and analysed data, Shuang Song, Xutong Wu wrote the paper.

The authors declare no competing interests.

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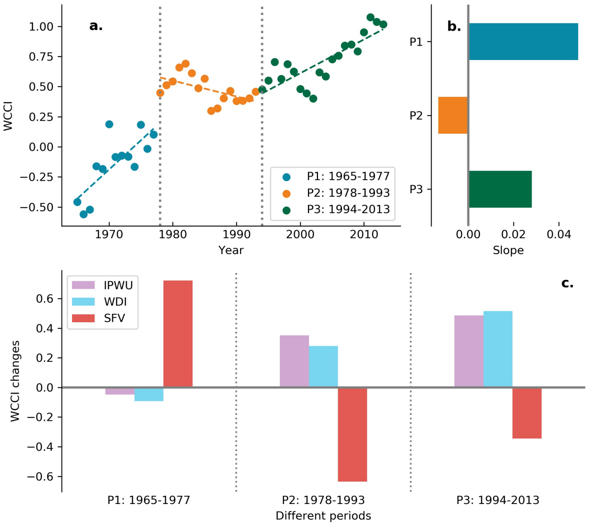

Fig. 1. Changes of the IWRU index. **A,** with two change points in 1978 and 1994, three periods were detected in trend of the IWRU. **B,** changes of IWRU in three periods have various slopes, while the second period have a negative growths rate. **C,** changes of the IWRU within three certain periods, which have different main contributors.

relationships between human societies and their water utilization. Then, by applying this index to the Yellow River Basin, China, we analysed water utilization regimes and their shifts in this typical basin of anthropogenic impacts, with change points detection and contribution decomposition methods following. In addition, combining model and data analysis, we further identify resource and development traps that have been exposed by regimes' shifting. Finally, refer to the existing theories, we summarized a general transition framework of water utilization regimes, which can be a useful guideline for basins to predict development traps and to develop in a coordinated way.

Results

Water utilization regimes. By the two significantly detected change points, the changes of IWRU index are split into three periods, whose slopes are various and mainly contributed by different factors 1. In the first period (P1, 1965-1978), the IWRU index had a rapidly increasing and the lightening of water stresses made the most striking contribution (xx%), while tendentiousness and pattern of the water utilization had slight negative contribution. In the second period (P2, 1979-1994), the IWRU index experienced a slight drop, despite positive contributions of tendentiousness and pattern of water utilization, because of increasing stresses on water resource playing a larger negative role (xx%). However, as the further increasing of positive contributions of water utilization tendentiousness and pattern, and decelerations of water stresses in the third period (P3, 1995-2013), a positive growth of the IWRU returned. Taken together, combining the three dimensions of water resources utilization, whose regimes have clear phase-characteristics with gradual transitions between different phases.

Changes between different regimes.

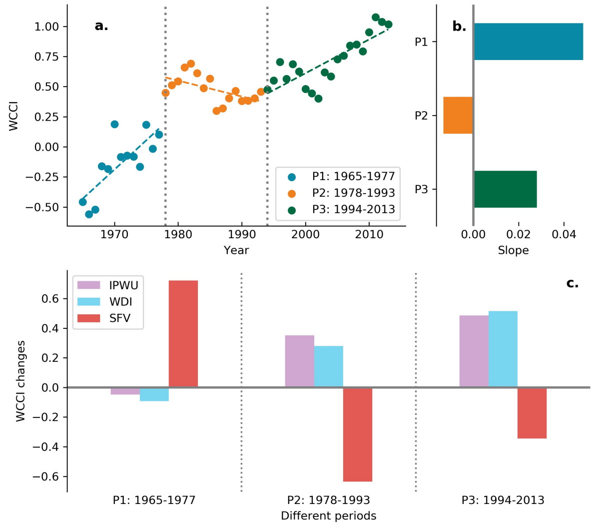

Fig. 2. Placeholder image of a frog with a long example legend to show justification setting.

Table 1. Comparison of the fitted potential energy surfaces and ab initio benchmark electronic energy calculations

Species	CBS	CV	G3
1. Acetaldehyde	0.0	0.0	0.0
2. Vinyl alcohol	9.1	9.6	13.5
3. Hydroxyethylidene	50.8	51.2	54.0

nomenclature for the TSs refers to the numbered species in the table.

Main drivers of the regime shifts.

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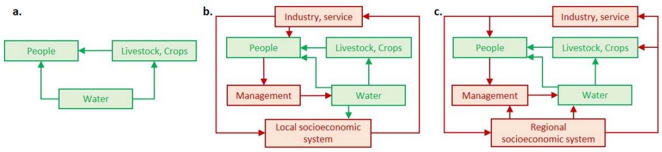

Fig. 3. Placeholder image of a frog with a long example legend to show justification setting.

Discussion

Transition Framework. Tables should be included in the main manuscript file and should not be uploaded separately.

Development Traps.

Materials and Methods

Please describe your materials and methods here. This can be more than one paragraph, and may contain subsections and equations as required. Authors should include a statement in the methods section describing how readers will be able to access the data in the paper.

Water utilization regime index. Example text for subsection.

Stresses. Various metrics, therefore, proposed for water stress (e.g. water scarcity, water stresses index, scarcity-flexibility-variability index), where the dimensions of human impact are increasingly valued. Among of them, by taking changes of water flexibility and variability into account, the scarcity-flexibility-variability (SFV) index focus more on dynamic responses to water resources in developing perspective, which considered a valid indicator of temporal changes in water stresses.

Lopsidedness.

Patterns.

Change points detection.

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