Water Resour Manage (2012) 26:3395–3414
DOI 10.1007/s11269-012-0078-1

The Development of Water Allocation Management in The Yellow River Basin

Chun Xia · Claudia Pahl-Wostl

Received: 27 July 2011 / Accepted: 17 May 2012 /
Published online: 3 June 2012

Abstract For decades, the Chinese government has been searching for solutions to cope with the increasing imbalance between the supply and demand of water in the Yellow River Basin. This paper aims at a better understanding of the development of the water allocation regime in the Yellow River Basin between 1950 and 2009, introducing a fresh perspective based on the notion of "regime transition". Accordingly, we investigated 1) whether so-called "Windows of Opportunity for Transition (WOPTs)" emerged, triggering a transition, and whether WOPT(s) resulted in a stable transition towards the new regime; 2) how informal learning processes and epistemic communities have contributed to the regime change. We adapted Kingdon's "multiple stream model" and identified four WOPTs from the 1950s, analyzing the reconfiguration process of the regime after the onset of the transition. Our examples of two types of informal learning processes demonstrate their contribution to the creation of WOPTs and the reconfiguration of the regime. Furthermore, this study indicates, in a qualitative manner, how epistemic communities contribute to the knowledge base of the regime, and thus to its development. Finally, we have provided a general insight into the further development of the water allocation regime and highlighted potential avenues for further studies.

Keywords Yellow River Basin · Regime transition · Water allocation · Informal learning · Epistemic communities

1 Introduction

The Yellow River, the second longest river in China, played an important role in China's socio-economic development. The river basin accommodates approximately 12 % of

C. Xia (✉)
The Wuppertal Institute for Climate, Environment and Energy, Wuppertal, Germany
e-mail: chun.xia@wupperinst.org

C. Pahl-Wostl
Institute of Environmental Systems Research, University of Osnabrueck, Osnabrück, Germany

China's population (Hu et al. 2005). However, its annual runoff provides only about two per cent of China's naturally available water resources (MWR 2006). The per capita renewable water availability is 530 m^3, which is far below the critical level for severe water scarcity of 1,000 m^3 per capita (Cai 2008). In recent decades, climate change has aggravated water scarcity in the basin. An obvious tendency of decreasing precipitation has been observed in the Yellow River Basin since the 1950s (Ding et al. 2007). In addition, water demand has increased dramatically due to the rapid socio-economic development in the basin. For instance, annual withdrawals from the Yellow River for human use totaled about 35.1 billion m^3 in 2008 (YRCC 2009), as opposed to 12.2 billion m^3 in the 1950s (Liu and Xia 2004). What is more, the interdependence of water users has grown, especially since the 1970s. Water use competition has dramatically intensified between upstream and downstream provinces as well as between the agricultural sector—still the largest water user—and the rapidly growing industrial sector (Cai 2008).

A number of excellent studies have been conducted to support water allocation in the Yellow River Basin (e.g. Shao et al. 2009; Xia et al. 2009; Zhao et al. 2009; Xu et al. 2002) as well as to explore the development of the water allocation regime in the Yellow River Basin (e.g. Wang 2005; Ma et al. 2007; Wang et al. 2008). This paper aims to provide additional inputs to the latter. Pahl-Wostl (2007) claims better understanding the dynamics of the development process of a regime is essential for supporting the regime to transition towards a desired status, e.g. an integrated and adaptive water management. However, the current studies on the development of the water allocation regime in the Yellow River Basin focused primarily on the outcomes of structural changes, in particular, institutional changes. No explicit, detailed investigation into the underlying process and dynamics of the regime development has yet been made. This paper will highlight this aspect, i.e. to investigate how the water allocation regime in the Yellow River Basin has developed since the 1950s.

2 Method

There is no universal definition of a regime. We applied the regime concept proposed by Van der Brugge (2009) to enable us to zoom in the water allocation regime and analyse the internal dynamics of the regime. He characterises a regime by three components: actor,[1] process[2] and structure. He distinguishes between three types of interconnected regime structure components: culture, institutions and physical infrastructure. The culture structure encompasses a management paradigm,[3] discourse, values and knowledge base. The institution structure contains regulative institutions, which can be described as "formal legal structures, regulatory frameworks, formalized professional rules of good practice as typically codified in professional handbooks" (Pahl-Wostl 2009). The physical infrastructure includes irrigation channels, for example.

A regime becomes unstable when the existing management paradigm is reflected upon and called into question. We claim that transition is triggered by the opening of a Window of Opportunity for Transition (WOPT). Our conceptualisation of WOPT was built on the "multiple stream model" of policy changes developed by Kingdon (2003), who stated that

[1] According to Van der Brugge (2009), the "actor" component includes both individuals and organisations.
[2] The "process" component connects actors to regime structures (Van der Brugge 2009). It can include management practices such as the decision-making process of water allocation.
[3] A management paradigm refers to strategic goals, problem framing and how to achieve these goals (Pahl-Wostl 2009)

"the probability of an (policy) item rising on a decision agenda is dramatically increased" when the coupling of three independent streams—problem, political, and policy stream—takes place. "Windows are opened by an event either in the problem or political stream," i.e. a problem window and a political window. A policy item is most likely to rise to the agenda when it is connected to both windows (Kingdon 2003). Given that regimes have a broader scope than policies, we redefine the three streams in Kingdon's model. First, according to Kingdon (2003), a political stream consists of "public mood, pressure group campaigns, election results, partisan or ideological distributions in Congress, and changes in administration" (Kingdon 2003). The scope of this stream needs to be reconsidered when applying the Kingdon model to the context of the Chinese political system and the water allocation regime. Firstly, elections in China and their results are not as influential as in western democratic countries. Secondly, the interest groups related to water allocation are the riparian governments and sectors that withdraw water from the river. Thus, the public mood is less relevant. Thirdly, for issues that may largely influence the socio-economic development across provinces, such as water allocation in a river basin, central government has the final say. In addition, the River Basin Commissions in China are only representatives of the Ministry of Water Resource (and thus central government) at the river basin level. Accordingly, the political stream in this paper focuses on 1) the struggles by interest groups to obtain more water and; 2) the ideologies, in other words, the paradigm of the central government for water allocation. The political stream is located in the cultural structure as well as the actor and process dimensions of the water allocation regime. It also reflects interactions between different geo-administrative levels within a regime, for example, negotiations between the central government and riparian provincial governments. An event in the political stream becomes a "political window" when a struggle between competing interest groups becomes significant or a paradigm change of the central government takes place. We claim that the latter case is the precondition for transition. The political window can be enlarged when the struggle becomes increasingly significant. Secondly, we define that a problem stream arises from interactions between a management regime and a landscape in which it is embedded. A landscape builds up an exogenous environment for the regime development (Geels 2004), consisting of a set of slow-changing components such as socio-political conditions as well as shocks such as dramatic ecosystem degradation. An event in the problem stream can become a "problem window" when mainstreaming actors, e.g. key decision-makers, are aware of or experience a significant mismatch between a management regime and the landscape or a crisis in the landscape. A problem window triggered by an external crisis can only develop into a WOPT if it coincides with a political window. The problem window can be enlarged when actors attach increasing attention to the problem. Thirdly, we rephrase the "policy stream" the "solution stream", which includes policy items, innovative infrastructures, change of decision-making processes, etc. Thus, this stream resides in all structural components as well as the process component of a regime. When the solution stream provides alternatives to match both the political window and the problem window that coincides with the political window, three streams join into one "single package." This creates a WOPT and triggers a regime transition. A transition is less likely to be triggered without such a critical joint. Even if the problem window and the alterative in the solution stream that represents a novel paradigm meet, this may not lead to a transition, due to the absence of a political window containing such a novel paradigm. On the other hand, although the joint of the problem window and the political window may momentarily "shake" the regime, such a "shake" is likely to fade without the alternatives provided by the solution stream (Kingdon 2003). However, not all WOPTs will result in a stable transition. The regime resists change since it has long been stabilised by the interdependence of all

structural components, actors and processes that have coevolved in the past. As transition starts, a new configuration of all these elements of a regime needs to be established in the solution stream. This immediate configuration process is essential for stabilising a transition towards a new regime, without which the regime state can easily revert to the original "basin of attraction".[4]

Growing evidence demonstrates that two components are essential for a successful regime transition by facilitating the opening of the WOPTs or by turning WOPTs into transformative change: informal learning processes[5] and epistemic communities (e.g. Gunderson et al. 2006; Linderman 2006; Olsson et al. 2006).

Informal learning processes prepare and navigate a transition by helping to identify problem and political windows, explore management alternatives and bring them into the regime, and develop strategies to reconfigure the regime (Olsson et al. 2006; Folke et al. 2005). The latter two add new elements to the solution stream. The *informal* nature of an *informal* learning process is manifested in the following two aspects. Firstly, the results of these processes are not legally binding. Secondly, the participants—both governmental and non-governmental actors—join the learning processes either inside or outside their obligations. The nature of these processes supports experimentation with new ideas, and leaves entrenched positions. It is claimed that informal learning only becomes effective for formal policy processes[6] when they are closely linked to them (Pahl-Wostl 2009).

An epistemic community, according to Haas (1992), is "the network[s] of professionals with recognized expertise and competence in a particular domain and an authoritative claim to policy-relevant knowledge within that domain or issue-area." Lindemann's case study (2006) on the transformation of European water management shows that epistemic communities contribute to the regime transition process by developing a shared understanding of problems, enhancing the knowledge base of the water management regime (i.e. the cultural structure of the regime) and thus reducing uncertainties. In addition, at the time of crisis or rapid change, epistemic communities probably become particularly influential, given the importance of knowledge in such situations. They can directly influence policy formulation by presenting decision-makers with causal models of issues at hand, redirecting various policy interests and suggesting alternative approaches to deal with the issues (Haas 1992).

Thus, to understand the development of the water allocation regime in the Yellow River Basin in the period from the 1950s to 2009, we have devoted special attention to:

- how the WOPT(s) emerged and whether they resulted in a stable transition to new regimes;
- how informal learning processes and epistemic communities have contributed to the development and transition of the water allocation regime.

Firstly, as noted above, we examined whether a WOPT emerged by identifying the joining of a problem window, a political window containing a new paradigm and a corresponding item in the solution stream. We then investigated whether reconfiguration took place in the regime structure to stabilize the transition.

Secondly, we highlighted key events in formal policy processes within a specific WOPT or a political window. Given the limited data availability, only key recent events were

[4] A "basin of attraction" refers to "a region in state space in which the system tends to remain" (Walker et al. 2004). It can be a regime and the social-ecological system operating under this regime (Van der Brugge 2009)

[5] Sometimes the informal learning process is called the "informal network" or "informal learning cycle". To emphasise the process aspect of this term, we use the term "informal learning process" here.

[6] Here, the formal policy process includes activities ranging from state/policy assessment, goal setting, policy formulation and policy implementation to monitoring & evaluation (Pahl-Wostl 2007).

analyzed in greater detail. Informal learning processes were then identified around these key events. Here we limited our attention to two types of informal learning processes: policy experiments and research projects, which are closely linked to formal policy processes. As noted above, common features of informal learning processes are: (1) no legally binding outcomes, and; (2) sufficient freedom is left for learning. Furthermore, we investigated the actors and outcomes of informal learning processes to understand how they are linked to formal policy processes and how these learning processes contributed to a transition.

Thirdly, for the purpose of analysis, we categorized two types of epistemic communities according to the origin of the experts (i.e. whether located inside or outside the management body). We then attempted to find evidence on whether each type has enhanced the knowledge base of the river basin water allocation regime and contributed to the regime transition.

A triangulation approach was employed for data collection. Literature review and document analysis were the main data collection methods. Data sources include governmental documents and reports, governmental websites, politicians' speeches, academic literature and media reports. In addition, face-to-face interviews with experts were conducted. The experts included one former staff member of the Water Diversion Department of the Yellow River Conservancy Commission (YRCC) and four researchers from two departments within the Yellow River Institute of Hydraulic Research (YRIHR) of the YRCC. A map with key activities at a specific stage of the regime development was used to help interviewees recall the informal learning processes that contributed to these key activities.

3 Historical Development of the Water Allocation Regime of the Yellow River Basin in the Period from 1950 to 2009

Two aspects of water allocation are presented: 1) riparian and ecosystem water allocation: water allocation among riparian provinces for their socio-economic development as well as to the ecosystem and 2) sectoral water allocation: water allocation among economic sectors.

During the 1950s, the central government set "Take Grain as the Key Link"[7] as a primary national development goal. Since the Yellow River Basin has always been one of the major agricultural areas in China, the agricultural sector was prioritised when it came to water withdrawal. Vast irrigation systems were established during this period (YRCC 2008a). The "*Comprehensive utilization plan of the Yellow River Basin*" formulated by the YRCC in 1954 specified that 47 billion of the 54.7 billion m^3 of natural runoff would be allocated to the agricultural sector (Ma et al. 2007).

Water use conflicts between several provinces took place during the irrigation peak demand period. Thus, the "*utilization plan*" included a first water allocation scheme among riparian provinces ("*1954 Scheme*") (Table 1). However, it was merely an irrigation water allocation plan, based on the irrigation areas and agricultural products of each province (Xue 2005). Additionally, due to the lack of legal status and attention from the central government, the "*1954 Scheme*" was not fully implemented (Ma et al. 2007).

In this period, the Yellow River was perceived as an unlimited water source. In fact, this perception existed throughout China's history. For a long time, Yellow River Basin management focused on flood management (Zheng et al. 2006). Consequently, water withdrawal was arbitrary. Despite such water use behaviour, flow remained sufficient for flushing sediment. The amount of water entering the sea was 48.1, 50.1 and 31.1 billion m^3 in the 1950s, 1960s and 1970s, respectively.

[7] Under this development goal, the whole country aimed at increasing grain production in all kinds of ways.

Table 1 Water allocation scheme in the 1954 River Basin Plan

Qinghai	Sichuan[a]	Gansu	Ningxia[a]	Inn. Mongolia	Shaanxi	Shanxi	Henan	Shandong	Hebei
4		4.5		5.73	4.7	2.6	11.2	10.1	7.74

a: Water allocation to Sichuan and Ningxia Provinces were not included in the 1954 Scheme. Ningxia Autonomous Region was not established at that time and its quota was integrated in that of Gansu Province. Sichuan only has a small part which belongs to the Yellow River Basin, which was probably why it was not included in the scheme

Source: Ma et al. (2007)

In the 1970s, water demand from riparian provinces increased significantly, due to the development of the industrial sector and the growing population. Conflicts among riparian provinces concerning water withdrawal increased. In 1972, the Yellow River dried up for the first time before reaching the sea[8]; interruptions have become frequent ever since (Fig. 1). However, the 1972 interruption did not gain central government's immediate attention (Hou 2011).

It was not until the early 1980s that water reallocation among riparian provinces in the Yellow River Basin hit central government's agenda. Meanwhile, from 1981 central government shifted its focus from hydraulic infrastructure construction to water management. In-depth research had been conducted to predict future water demand (not only the water demand of irrigation, but also that of the industrial and domestic sector) and water resources in the Yellow River, based on which the Ministry of Water and Hydropower proposed suggestions on water allocation. (YRCC 2008b). In 1987, a new "*Yellow River water allocation scheme* [No. 61]" (State Council 1987), based on the research outcomes and consultation with riparian provinces, was approved by the State Council. It allocated initial water use rights to all riparian provinces as well as the ecosystem, in the period before the operation of the South-North Water Transfer. The total annual runoff of 58 billion m^3 was divided into two parts: 37 billion m^3 as the maximum water supply capacity to human use (Table 2) and 21 billion m^3 for sediment flushing. This was the first time the negative consequences of water overexploitation on ecosystem functions were formally considered in water allocation.

Water withdrawal was legalised at the national level during this period. In 1988, the first *Water Law* specified that a Water Withdrawal Permit (WWP) system should be applied for all water abstraction .[9] In 1994, the Ministry of Water Resource (MWR) empowered the YRCC to organise the WWP and Total Amount Control (TAC)[10] for all riparian provinces based on the "*1987 Scheme*".

In spite of establishing the "*1987 Scheme*" and introducing the WWP & TAC system, riparian provinces often violated the rules. Firstly, incentive mechanisms for riparian provinces and water user groups were not set up by central government. Secondly, despite being authorised by the MWR, the YRCC had very limited powers to enforce water diversion. As a ministry, the MWR has insufficient power to influence provincial governments. Thirdly, water allocation was not managed by the YRCC alone. The YRCC was only in full charge of water allocation at the downstream section of the river. Water allocation of the upstream and middle stream had long been decided by the Yellow River Upstream Water Diversion

[8] This will be referred to as "interruption" in the paragraphs that follow.
[9] There are certain exemptions, such as for livestock and domestic purposes in rural areas and rural collectives taking water from their own ponds and reservoirs.
[10] The TAC refers to the total water withdrawal quantity allowed for an administrative unit.

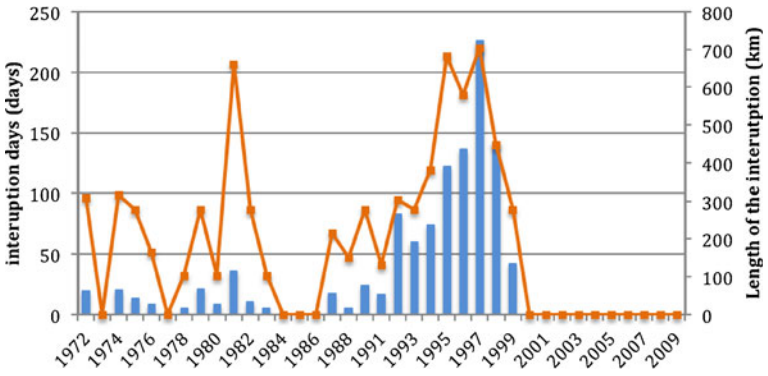

Fig. 1 Interruption days and length of the Yellow River

Commission, which consisted of the YRCC, the North-West Electricity Management Department, the Dam Management Departments and the governments of upstream riparian provinces. Fourthly, the "*1987 Scheme*" only specified an annual water consumption quota, i.e. annual water use rights, in normal years and failed to consider uncertainty due to natural intra- and inter-annual variability (YRCC 2008b; Shao et al. 2009). Finally, the enforcement of WWP & TAC was also ineffective due to the difficulty of monitoring, for example (Wang 2003b).

Additionally, due to the change in national economical priority from agriculture to industrial and urban development, the Water Law issued in 1988 stipulated that the priority of the WWP should be given to water use in the domestic and important industrial sector, instead of the agricultural sector. In most provinces, however, water use rights for sectors were not clearly specified. Thus, while agricultural water use continued to be intensive, arbitrary and inefficient, the industrial sector faced severe water shortages (Hu et al. 2005).

Since the 1980s, the Yellow River Basin has experienced rapid development. The riparian provinces have become more focused on economic development due to the market-oriented reforms initiated since 1978. The population also grew rapidly. These developments demanded significant quantities of water and resulted in increased conflicts over water allocation among riparian provinces. In the 1990s, the exploitation rate[11] of the Yellow River reached almost 70 % (Lin and Deng 2003).

As a result, water allocated for the river ecosystem was abstracted for human use. The amount of water entering the sea in the 1990s reached 14.1 billion m^3, about 30 % of that during the period from 1950 to the 1960s. In addition, the river flow dried up before reaching the sea every year between 1987 and 1997. In 1997, the interruption was sustained for 226 days over a length of 704 km (Fig. 1). The interruption brought enormous loss to the riparian regions, especially to the industrial and agricultural sector (Wang et al. 2008).

In response, the former Vice Premier Wen Jiabao urged that the Yellow River issue should be placed on central government's agenda. At the end of 1998, the State Planning Commission (SPC)[12] and MWR formulated the "*Administrative Measures of Yellow River Water Diversion*". It stipulated the principles and procedures of water diversion and authorised the YRCC to undertake unified water diversion to ensure the enforcement of the "*1987 Scheme*". Considering variations between different years and within each year, the YRCC

[11] The exploitation rate refers to the proportion between water supply by the river (covering at least 75 % of water demand) and the average annual water resource of the river in recent decades.
[12] The current National Development and Reform Commission (NDRC)

Table 2 1987 Water allocation scheme

Qinghai	Sichuan	Gansu	Ningxia	Inner Mongolia	Shaanxi	Shanxi	Henan	Shandong	Hebei	Tianjin
1.41	0.4	3.04	4	5.86	3.8	4.31	5.54	7	2	

formulated an annual water diversion plan with detailed monthly water allocation quota. According to different natural runoff and storage rates in the reservoirs. The "*1998 Measures*" addressed the shortcomings of the "*1987 Scheme*", for example, it specified the principle of "the same increase proportions of water diversion to all provinces in the wet year and the same reduction proportions in the dry year." In 2003, the YRCC specified the critical level of discharge of various important river sections. When the discharge falls below the critical level, water abstraction in certain provinces is severely constrained or even stopped (Xue 2005). Despite a more stringent and improved water allocation institutional framework, water allocation did not always follow the rules. For example, during the 2002 drought, after its "tactic begging", downstream Shandong Province obtained an additional 0.8 billion m^3 of water from the State Council to support its irrigation at the cost of reduced water allocation to two upstream provinces. However, these two provinces were not compensated (Wang 2003c).

In 2006, based on the experiences gained from the implementation of the "*1998 Measures*", the State Council issued "*Yellow River Water Diversion Regulation [No. 472]*" (*State Council, 2006*). It was the first regulation on water allocation at the river basin level in China. This regulation aims to ensure strict compliance with the "*1987 Scheme*" by riparian provinces. It stipulates that province governors should take full responsibility for violations. In addition, it specifies that the annual water diversion plan should be developed by the YRCC in consultation with water resource or management bureaus of all riparian provinces[13] and reservoir management bureaus, and be approved by the MWR. This consultation process is described as very hard by the water diversion bureau of the YRCC. It involves severe conflicts between riparian provinces, which are often settled by commands from central government (Xi 2010).

Meanwhile, the water management paradigm at the national level has also evolved. After the national flood in 1998, central government reflected on the existing water management regime that had focused exclusively on fulfilling human needs by applying an engineering-oriented approach. Consequently, the MWR stated that the water management paradigm would change from "hydraulic engineering" towards "resource water conservancy" (Wang 2003a), which aims at achieving "harmony between human and nature" and emphasises the importance of the institutional dimension of water management. Theories of market instruments, such as water rights and water markets, were proposed by both MWR and the scientific community. In 2001, the MWR proposed new strategic goals for Yellow River management. "To ensure the Yellow River (physically) reaches the sea" was among these goals (YRCC 2001). At the YRCC working conference in 2004, the Director of the YRCC announced "maintaining the health of the Yellow River" as the vision of Yellow River management. Following this vision, the strategic goal of water allocation is to ensure "environmental water needs, that the Yellow River (physically) reaches the sea" (Li 2004).

[13] Henan River Management Bureau and Shandong River Management Bureau, affiliated to the YRCC, are in charge of water allocation in Henan and Shandong Province.

The WWP system at both national and river basin level has also been further developed. In 1999, the MWR further enhanced the YRCC's authority to enforce the WWP & TAC based on the water diversion procedure specified by the "*1998 measures*". In 2002, the *amended Water Law* stipulated that water use rights shall only be obtained once water users have obtained a WWP and paid the associated water fees. In the same year, the YRCC formulated the "*Administrative Measures of the WWP & TAC in the Yellow River Basin (interim)*". Under this "*Measures (interim)*", the total water consumption by a specific province, i.e. the total WWP issued by the YRCC and water management departments at different administrative levels minus the total water amount returning to the main stream and tributaries of the Yellow River, should not exceed the amount assigned by the water allocation scheme approved by the State Council (YRCC 2008a). In addition, it specified that the approval of WWP applications by new, expanded and retrofitted projects should be suspended for those provinces (and regions) which already abstract all water allocated to them and do not have additional new quota allocated by the YRCC. In 2006, the State Council issued the "*Ordinance of Water Permits and Water Resource Fee Management (No. 460)",* which stipulated that provincial or Autonomous Region governments are in charge of allocating WWP to its cities and counties. In 2007, the YRCC started to work with riparian provinces on the water use allocation to different administrative levels within these provinces (MWR 2007). Such a detailed allocation of WWP is essential for allocating and diverting water in the main stream as well as the tributaries of the Yellow River.

During this period, the Yellow River Basin experienced a further boom in industrial development, resulting in increased tension between water supply and demand, especially in the industrial sector. However, the agricultural sector still used water arbitrarily. Since 2003, water use rights exchange between the agricultural and the industrial sector has been experimented with upstream. To guide and support the implementation of this new policy tool, the "*Administrative Measures of water rights exchange in the Yellow River Basin (Interim)*" and the "*Approval Method of water-saving infrastructures for water rights exchange in the Yellow River Basin (Interim)*" were formulated in 2004 and 2005, respectively. The "*Ordinance (No. 460)"* (State Council, 2006) also opened the door for water rights trading if it can be demonstrated that the amount of water to be traded is saved by adjusting products and industrial structure, applying water-saving production processes, etc. In 2009, a new WWP & TAC policy issued by the YRCC—"*Implementation details of WWP management in the Yellow River Basin*"—replaced the "*Measure (interim)"*. It stipulated that those projects that are unable to gain WWP approval based on "*Measures (interim)*" can now obtain WWP through water use rights exchange projects approved by the YRCC.

It is worth noting that the establishment of Water User Associations (WUA)[14] in different irrigation districts played an important role in the implementation of water use right exchange between the agricultural and the industrial sector. Since Chinese farmers had many small scattered plots of land, it was very difficult to monitor volumetric water use at farm level (Xie et al. 2009). The exchange of water use rights has been facilitated by entitling WUAs to have water use rights. However, agricultural water users have little knowledge of their water use rights and have not been compensated for transferring the quantity of water they saved to industry. In addition, water rights exchange pilots have not reflected market signals (Cenacchi et al. 2010; Wang and Zhang 2010).

[14] WUA is an organisation consisting of agricultural water users in a specific hydrological (recommended) or administrative unit to manage water-related issues.

From 1999, ecosystem degradation in the Yellow River Basin significantly slowed down and no interruptions have occurred in the mainstream of the Yellow River since. Despite the low natural runoff between 2000 and 2002,[15] the river flow in the mainstream still reached the sea (Fig. 1). However, studies point out that the critical level of river discharge set at different sections for preventing physical "interruption" was too low to meet the water need of the river ecosystem to fulfil its different functions (Ni and Qian 2002). At the YRCC working conference in 2008, Director Li proposed "to ensure the integrity of river ecosystem functions"[16] as a new strategic goal of Yellow River management. Research has been initiated by the YRCC to develop strategies to achieve this new strategic goal.

4 Discussion

4.1 How the WOPT(s) Emerged and Whether They Resulted in a Stable Transition

At the beginning of the1950s, we observed a problem window in riparian and ecosystem water allocation: central government was aware that some provinces' water demand could not be met during the peak demand season. Conflicts between riparian provinces became severe, opening a political window. This political window also contained central government's awareness of formal institutions' needs for water allocation among riparian provinces, which represented a new paradigm of water allocation. The "*1954 Scheme*" emerged from the solution stream. Consequently, a WOPT opened for the riparian and ecosystem water allocation, and triggered a transition in this part of the regime to that regulated by formal institutions for water allocation. However, reconfiguration of the regime was insufficient after the opening of this WOPT. For example, no mechanisms were developed to enforce the "*1954 Scheme*". Meanwhile, the political stream was dominated by a paradigm that focused on the new construction of water diversion infrastructures, and neglected the management dimension of the water allocation regime. Accordingly, the regime reverted to the original "basin of attraction".

In 1972, a significant event took place in the problem stream: the first interruption of the Yellow River. However, this event did not become a problem window immediately. It hardly gained the attention of governments at various levels. A problem window opened from the beginning of 1980s: central government became aware of the frequent interruptions that occurred in the 1970s. Meanwhile, a political window opened containing the following components: 1) conflicts over water allocation between riparian provinces increased significantly; 2) the central government shifted its focus of water management from new infrastructure construction to management; 3) central government became aware of the urgency of establishing formal institutions for water allocation within riparian provinces; 4) there was an awareness of the negative impact of the human over-exploitation of ecosystem services and needs of allocating water to the river ecosystem. These components were, in fact, not in line with each other. For example, the fourth component potentially contradicted the first one. The fourth component represented a new paradigm of water allocation. Meanwhile, events had also taken place in the solution stream, such as studies on water resources and water demand in the river basin. A formalised institution—the "*1987 Scheme*"—arose and

[15] The natural runoff measured at Huayuankou station, the discharge control station for entering the lower reach, was 37.1 %, 41.9 % and 46 %, respectively. It was lower than the average natural runoff since 1919.
[16] This goal refers to an enhancement of biodiversity and ecosystem functions of water supply for sediment transport, flood mitigation and self-purification (An 2009).

was picked up by central government in 1987, which joined the problem window and the political window. Thus, a WOPT for riparian and ecosystem water allocation opened at this point and triggered a transition in this part of the regime to that regulated by formal institutions, taking into account ecological sustainability.

Meanwhile, sectoral water allocation had evolved. A political window opened: the strategic goal of the river basin water allocation regime was shaped by the change of the national development priority, which prioritised domestic and important industrial water use. However, the solution stream did not provide any alternatives that could combine with the political window and the problem window. Thus, no WOPT opened in this part of the regime. Intensive low-efficiency water use by the agricultural sector continued.

After the opening of the WOPT for riparian and ecosystem water allocation, the WWP & TAC system, a new legalised component of the national water allocation regime, was added to the institutional structure of the water allocation regime at the river basin to support the implementation of the "*1987 Scheme*". However, a lack of other institutions (e.g. incentive mechanisms) as well as the unchanging actor and process dimensions (e.g. the decision-making structure of water allocation) in the regime inhibited the enforcement of the "*1987 Scheme*". The immediate reconfiguration in the solution stream was thus insufficient. Meanwhile, the water demand of riparian provinces and their conflicts over water allocation, which potentially competed with the idea of allocating water to the river ecosystem, had increased. This means that the political window was kept open and enlarged. This, combined with insufficient reconfiguration, resulted in a low stability of transition to a new regime. Accordingly, the regime reverted to the original "basin of attraction".

Water allocation planned for the river ecosystem was abstracted for human use, which led to a dramatic degradation of the Yellow River ecosystem. The interruption continued and peaked in 1997. This significantly raised the central government's awareness of the degradation of the Yellow River ecosystem. Three new components were added to the political window that opened at the beginning of the 1980s: 1) central government realised the urgency of conserving the river ecosystem and ensuring its services; 2) central government announced a new paradigm of water resource management that aims to achieve "harmony between human and nature"; 3) the central government stressed the institutional dimension of water management and, in particular, market instruments. The first two aspects were reflected in the emergence of the new strategic goal: "ensuring the Yellow River (physically) reaches the sea" as stressed by the MWR (2002) and YRCC's new vision of "maintaining the health of Yellow River" (2004). The "*1998 Measures*" that emphasised a stringent enforcement of the "*1987 Scheme*" and authorised the YRCC to undertake unified water diversion arose from the solution stream and was taken by the central government to join the problem window and the political window. This joint was another WOPT for riparian and ecosystem water allocation, which triggered a transition of this part of the regime to that regulated by formal institutions and aiming at ecological and economic sustainability.

Meanwhile, a new component entered the problem window: central government's awareness of the dramatically increased demand of the industrial sector and arbitrary water use by the agricultural sector. The experimentation and institutionalisation of water use rights exchange between the agricultural and industrial sector emerged from the solution stream, which matched this problem window and was in line with the third component of the political window described above—the emphasis on market

instruments. This joining opened a WOPT for sectoral water allocation, which triggered a transition in this part of the regime to an economically sustainable regime.

After WOPTs opened in these two parts of the regime, a reconfiguration process started to stabilise the regime, for example, in its institutional structure, which included the following aspects: improvement of the implementation details of the "*1987 Scheme*", legalisation of water allocation and diversion in the river basin ("State Council, No. 472, 2006"), the further development of the WWP & TAC system, political incentives provided for provincial governors, formulation of policies for water use rights exchanges at both national and river basin level (e.g. "State Council, No. 460, 2006") and the detailed allocation of WWP to different administrative levels. Besides, the process dimension of the regime has also evolved to stabilise the transition of the regime, such as the authority given to the YRCC for unified water diversion. In addition, experiments in water use rights exchange were also facilitated by the implementation of WUA, which was not initially located in the solution stream of the water allocation regime. These immediate reconfiguration processes after the opening of WOPTs increased the stability of the transition to the new regime. However, although reconfiguration involves changes in the process dimension, we observed that the top-down approach remained the dominant approach for solving conflicts in water allocation and diversion. This approach is not sustainable from either economic or social perspectives. In addition, the YRCC is still limited in its power of supervision and sanction of violations by local governments (Wang and Zhang 2010).

The change in regime since 1998 resulted in an improvement of the river ecosystem: since 2000, the Yellow River has managed to reach the sea every year. However, another problem window opened: the YRCC realised that the existing strategic goal of "ensuring the Yellow River (physically) reaches the sea" may not be sufficient for achieving the vision of "maintaining the health of the Yellow River". Meanwhile, the YRCC announced a new strategic goal of the water allocation regime—"to ensure the integrity of river ecosystem functions" in 2008, which opened a political window. Alternatives that could join up with the problem window and political window were lacking in the solution stream. However, the YRCC has been searching for a solution, for example, by initiating research on the "*Plan of ensuring the integrity of river ecosystem functions in the Yellow River Basin*", described below.

4.2 Informal Learning and Epistemic Communities Supporting the Regime Change

In this section, we first demonstrate some examples of informal learning processes and analyse how these processes contributed to the water allocation regime change in the Yellow River Basin. We then present two types of epistemic community and analyse the roles they played in the regime development.

To understand how informal learning processes contributed to the regime change, we first identified the following key recent events in formal policy processes within a specific WOPT or a political window containing a new paradigm:

- The Yellow River issue hit central government's agenda (1998)
- Formulation of "*Administrative Measures of Yellow River Water Diversion*" (1998)
- MWR's announcement of the strategic goal "to ensure the Yellow River (physically) reaches the sea" (2001)
- YRCC's strategic vision of "maintaining the health of the Yellow River"(2004)

- Formulation of policies for water use right exchange between sectors (2004 and 2005)
- Announcement of the strategic goal of "ensuring the integrity of river ecosystem functions" (2008)

4.2.1 Examples of Informal Learning Processes

As noted above, informal learning processes investigated in this paper include two types of process—policy experiments and research projects, which are closely connected to the key events listed above.

Policy Experiment Policy experiments in China are usually initiated by the government. The members join this kind of informal learning process due to the obligations their positions involve. This makes up the "formal" feature of policy experiments. As mentioned above, however, the "informal" nature of policy experiments in this study is that they do not aim at a legal binding outcomes and are not formally binding policy implementation process. It is a process where freedom for exploring innovative policy implementation is provided. The experiment on water use rights exchange is well known in recent Yellow River management practices. This experiment explored the possibility of transferring water use rights between different sectors to optimise the economic efficiency of water use.

Inner Mongolia Autonomous Region was highly dependent on water resources diverted from the Yellow River. Due to its upstream advantage, the region often used more water than the quotas assigned to it by the "*1987 Scheme*". The violation became increasingly difficult after the creation of the "*1998 Measures*", the "*Measure (interim)"* issued in 2002 and the "*Yellow River Water Diversion Regulation*" issued in 2006. The initiation of industrial projects was largely constrained by the limited water quota assigned to the region (YRCC 2008a). Given requests by the industrial sector and the YRCC's refusal to allocate more water, the Inner Mongolian government realised that traditional supply-oriented water management would not enable a compliance with the "1987 *Scheme"* and regional economic development. Thus, they consulted the YRCC about possible management innovations.

In Inner Mongolia, the agricultural sector has long received a dominant share of water allocation (95 %). Its water use efficiency, however, was very low. For example, average canal efficiency was about 40 % (YRCC 2008a). Water allocation for the rapidly developing industrial sector was less than 3 %, resulting in continuous water shortages in this sector (MWR 2004). Inspired by the theories of water markets at national level, the YRCC suggested that the Inner Mongolian government experiment on water use rights transfer between the industrial and agricultural sector within the region (YRCC 2008b), i.e. the industrial sector should provide funding for water-saving infrastructure for irrigation and would receive the quantity of water saved that was originally assigned to the agricultural sector. However, the transfer of the WWP was not permitted by the "*Implementation Measures of the WWP*", issued by the State Council in 1993.[17] Thus, the YRCC used a different label—"water rights *exchange*" instead of "water rights *transfer*". The first round of the experiment started in 2003 with five pilot projects. The experiment was later expanded to 26 projects (Li 2010).

[17] Article 26 of the "*Implementation Measures*": "transfer of the WWP certificate is forbidden….". According to the Water Law (2002), water rights in China belong to the state.

Accordingly, the Inner Mongolian government developed "*the overall Plan of Yellow River water rights exchange"*. Both the "*Plan"* and the projects of water use right exchange between a specific company and the Irrigation District were approved by the YRCC (YRCC 2008b).

To support the experiment, policies that guide and regulate water use rights exchange were formulated by the MWR, the YRCC and the Inner Mongolian government. The MWR formulated the "*Guideline for piloting water use right exchange in the Inner Mongolia and Ningxia part of the Yellow River*" in 2004. As mentioned above, the YRCC also formulated two interim policies to facilitate the experiment. In addition, to ensure the implementation of the experiments, leader groups have been established at the Autonomous Region, municipal and township level (WET 2006).

During the experiment, the YRCC and the Inner Mongolia Water Management Department (WMD) separately conducted medium-term checks. The final evaluation was organised by the YRCC and the WMD (researcher at the YRIHR, personal communication 25 March 2010).

Erdos City was chosen for the first round of the water right exchange experiment. Despite the implementation of the "construction of Water Saving Society", conflicts between water demand and water supply increased continually in the city (Li 2010). The pilot projects conducted during the first round of the experiment were unable to resolve the conflict. Thus, in 2009, the YRCC agreed to start the second round of the water use rights exchange experiment in Erdos. A new exchange method was jointly developed by the regional government and the YRCC. According to the new method, with the exception of improving the quality of canals, investments from the industrial sector would further contribute to adjusting the cultivation structure, modernising agriculture with advanced irrigation technologies, etc. (researcher at the YRIHR, personal communication 26 March 2010; Erdos Government 2009).

To sum up, policy experiments on water rights exchange have enhanced the knowledge base for the new policy instrument and thus reducing the uncertainties of its implementation and partly led to the development of formal institutions and organisational structure of the new policy instrument in the regime in transition. However, they have been implemented in a scattered rather than systematic manner in the Yellow River Basin to satisfy local needs (Cenacchi et al. 2010). In addition, water rights have been transferred from a specific irrigation district to a specific power plant, involving high transaction costs (Wang 2009). The lessons learned from these experiments have not yet been generalised.

Research Projects The first example is a short-term research project initiated by the Chinese Academy of Science (CAS) and the Chinese Academy of Engineering (CAE)[18] (former staff of the Water Diversion Department, personal communication 30 March 2010). Due to the increasing degradation of the Yellow River, the "academicians" of CAS and CAE initiated a protest of "Let's act to save the Yellow River!" in January 1998. It was followed up by a short field trip in June, which resulted in a policy brief of "*suggestions and solutions of alleviating interruption in the Yellow River*". It claimed that the human dimension was the major cause of the "river interruption". Possible solutions were put forward. These solutions included urging the State Council to approve the "*1998 Measures*", integrated water allocation management (such as considering both water quantity and quality as well as

[18] These two institutes are among the best research establishments in China."Academicians" from these institutes have a very high social standing and academic credibility, and their suggestions are often followed by governments at different levels.

surface water and groundwater in allocation), applying proper water price mechanisms to regulate water demand and suggesting the formulation of the "Yellow River Law" and changing the organisational structure of Yellow River water management (CAS 2005). As a result, the former Vice Premier Wen Jiabao urged that the "interruption" problem of the Yellow River needed to be put on central government's agenda, and requested the MWR to conduct studies for the key issues identified in the "*Policy Brief*". In addition, he stated that he would personally guide further discussions based on study results and forward these results to the State Council (YRCC 2002).

Secondly, after the announcement of the strategic goal of "maintaining the health of the Yellow River" in 2003, research projects were initiated by YRCC decision-makers to turn this strategic goal into concrete measures. One major project was awarded to the YRIHR, a research institute affiliated with the YRCC. The project aimed to identify the concrete objectives and approach required to rehabilitate the Yellow River. The data collected and the management techniques developed during the project were partly used as input for the "*Integrated Plan of the Yellow River Basin*" (researcher at the YRIHR, personal communication 25 March 2010). Similarly, research projects were launched by YRCC decision-makers after Director Li's recent statement of the new strategic goal—"to ensure the integrity of river ecosystem functions". One major project that aims to develop a framework of how to realise this strategic goal was awarded to the YRIHR, Water Diversion Department (WDD) and Water Resource Protection Department (WRPD) of the YRCC. The latter two will be the potentially major actors involved in implementing new policies that aim to achieve the new strategic goal. Thus, the project also provided chances for both actors to develop a common understanding about what is the new strategic goal, and how to achieve it. Besides, the results of the project are expected to serve as input for the future "*Plan of ensuring the integrity of river ecosystem functions in the Yellow River Basin*" (researcher at the YRIHR, personal communication 25 March 2010).

4.2.2 Examples of Epistemic Communities

The first type of epistemic community contains specific organisational units within the YRCC that function as epistemic communities and provide expert advice for policy-making. For example, the YRIHR—the affiliated research body of the YRCC, established in 1950—is a research centre with expertise in various fields of river basin management and a long-term epistemic community. Its Water Resource Institute (WRI) is one of the major actors that have contributed to the knowledge base of the recent development of the water allocation regime. Their contributions included improving the understanding of water use rights and water use rights exchange, and building up the policy framework and evaluation systems of the new strategic goals of the water allocation regime (researcher at the YRIHR, personal communication 25 March 2010).

The second type refers to a long-term epistemic community that consists of both internal and external experts of the YRCC. The Science and Technology Committee (STC) of the YRCC is a community of this type. It is a consultant unit for YRCC decision-making, whose members are invited by YRCC decision-makers. These members are senior experts of water resource management, hydraulic engineering, etc. They come from various prominent research institutes and organisations inside or outside the YRCC, such as CAS and CAE. The STC's activities range from providing advice on important strategic decisions to conducting feasibility analyses and the monitoring and evaluation of key projects. The STC holds annual meetings, where members communicate their research results about the

Yellow River to YRCC's decision-makers and decision-makers consult them with regard to management problems and key projects. These consultation topics have often been set as the objectives of research projects conducted by the STC the next year. In 2010, for example, consultant topics concerning the water allocation regime included water use rights exchange between sectors in the Inner Mongolia and Ningxia Autonomous Regions and water use rights exchange between tributaries of the Yangtze and Yellow River within Shaanxi Province (researcher at the YRIHR, personal communication 26 March 2010).

4.3 Contribution of Informal Learning Processes and Epistemic Communities to Regime Change

Table 3 depicts the linkages of informal learning processes to formal policy processes and their contributions to the transition of water allocation regime .

Table 3 Informal learning examples and their links to the formal policy process and contribution to the water allocation regime transition

Informal learning example	Actors		Contribution to regime change
	Leading	Their links with formal policy process	
Short-term research project conducted by CAS and CAE	CAS and CAE (national level)	Long-term influence on the development of formal policies at the national level	• Contributing to the recognition and the causal model of the problem window; • Contributing to the formation of the political window; • Creating alternatives in the solution stream by suggesting medium-and long-term frameworks with a new paradigm
Research project following the announcement of "maintaining the health of the Yellow River" as a strategic goal	YRIHR (YRCC)	Within the formal policy process	Creating alternatives in the solution stream that match the political window
Water use rights exchange experiments	Inner Mongolia Region government and its WMD and the YRCC	Within the formal policy process	• Creating alternatives in the solution stream that match the political window • Contributing to the reconfiguration of the regime structure (institution structure) after the WOPTS
Research project following the announcement of "ensuring the integrity of river ecosystem functions" as a strategic goal	YRIHR, WDD, and WRPD (YRCC)	Within the formal policy process	• Creating alternatives in the solution stream that match the political window

The results show that informal learning processes can contribute to the creation of WOPTs and reconfiguration after a transition has been triggered. It is worth noting that these informal learning processes were closely linked to the formal policy process. On the one hand, actors who led the informal processes were either active in or had a strong influence on formal processes. On the other hand, some informal processes were initiated from formal policy processes. It is such close links that are required for informal learning processes to contribute to the learning of formal policy processes.

In addition, the experiment of water use rights exchange also demonstrates the capacity and freedom of learning in informal learning processes. Whilst the first round of the experiment explored the possibility of investing in water supply infrastructure to save water, the YRCC and the regional government reflected on whether water demand could be reduced by changing water users' behaviour, i.e. changing the agricultural product structure, in the second round. Besides, it is thought that the policy experiment process provided a social learning platform among stakeholders. Thus, such a learning process added alternatives to the solution stream and stabilised the transition.

The examples of epistemic communities demonstrate that these two types of epistemic community contributed to enhancing the knowledge base for the development of the water allocation regime that is inherent with high uncertainty. Although the first type of epistemic community in China was often regarded as "followers" of their leading agency, who had tuned their advice to "follow their master's voice", they have become more independent due to recent government restructuring and reform (Wu and Wang 2007). In addition, the second type that integrate communities across the boundaries of formal organisational units enables open communication of the knowledge generated from the first type of community that are more constrained by the prevailing paradigm of such an organisation within the governmental agency. This crossing of boundaries in turn creates dynamics in the knowledge base of the regime to avoid "the risk of 'group thinking' that creates false certainty" (Arentsen et al. 2000). Such a crossing of boundaries is complemented by project-based network activities initiated by the YRCC itself or co-initiated by the YRCC and national and/or international organisations and research institutes. For example, in 2005, the second International Yellow River Forum focusing on "Maintaining River Health and integrated River Basin Management" was co-organized by the YRCC, prominent national research institutes, and international organisations. During the Forum, theories and practices to achieve this new strategic goal of Yellow River management were discussed among YRCC water managers and national and international experts (researcher at the YRIHR, personal communication 25 March 2010). Such a network, where the YRCC hear innovative ideas and exchange views with the national and international professionals, can foster high level of mutual learning.

However, we found no strong evidence that knowledge generated by these epistemic communities contributed directly to the creation of WOPTs during the rapid change of the water allocation regime.

5 Conclusion

This study has contributed to a better understanding of the development of the water allocation regime in the Yellow River Basin since 1950. Instead of focusing exclusively on the kind of structural change that occurred to the regime, we explored how and why the regime has changed.

Firstly, we adapted Kingdon's "multiple stream model" to investigate how a regime transition was triggered, i.e. by identifying WOPTs. Three WOPTs for riparian and

ecosystem water allocation and one WOPT for sectoral water allocation were identified. However, the regime transition caused by the first two WOPTs for riparian and ecosystem water allocation reverted to the original "basin of attraction", due to the insufficient reconfiguration in the new regime. Additionally, we observed the emergence of political windows or problem windows that did not trigger a regime transition, demonstrating that a transition is less likely to start without a critical joint of all three streams.

Secondly, in spite of the limited number of interviewees, our study shows that two types of informal learning processes—policy experiments and research projects—contributed to the creation of WOPTs and the reconfiguration of the regime after the opening of WOPTs. The contribution was enabled by the effective links of these informal learning processes with formal policy processes. These links include leading actors of the informal learning process who are active or influential in the formal processes and the need from the formal process of initiating informal learning. It is worth noting that the experiment of novel policy instruments is a popular learning strategy initiated by governments at different levels in China, in which protection spaces (e.g. exempting from the existing regulations) are provided to explore the complexity and uncertainty of policy implementation (Heilman 2008; Xia and Pahl-Wostl in review). This results in innovative policy implementation, as demonstrated in our example. In addition, this study indicates, in a qualitative manner, the contribution of epistemic communities to the knowledge base of the regime, and thus its development. We found no strong evidence of a direct link between epistemic communities and the opening of WOPTs. However, given the continuous knowledge input from these communities, it can be expected that the alternative approaches and causal models of problems proposed by these communities can possibly be picked up by decision-makers of the YRCC at the time of crisis or rapid change.

Finally, with the opening of WOPTs and immediate reconfiguration, the current water allocation regime transitioned into a more effective and sustainable regime. However, reconfiguration must speed up, for example, by enhancing YRCC's power of supervision and sanction on water withdrawal. In addition, another political window needs to open in order to achieve a more economically and socially sustainable water allocation regime that can cope with climate variability and change as well as other uncertainties, which attached importance to: equity among water users (e.g. farmers, or the province whose water quota is reallocated to other provinces should be sufficiently compensated), the "real" or "quasi-" market of water use rights, the explicit consideration of climate change and the possibly reduced amount of usable water transferred from the South-North Water Transfer project.

While formal policy-making processes are essential for the further regime development mentioned above, informal learning and epistemic communities are also crucial. They can be purposefully created to provide solutions for political windows and reconfiguration as well as to catalyse the opening of political windows.

The analysis of WOPTs has provided fruitful insights into how a transition starts in the water allocation regime in the Yellow River Basin. We focused on the moment in time when political windows and problem windows opened as well as on the alternatives chosen by the solution stream. A further study on the development process of streams would be interesting, for example, how different actors at different levels and modes of governance interact and cohere to create a political window and to develop and select an alternative from the solution stream. In addition, the reconfiguration process of the regime in this paper focused primarily on the institutional component. A systematic and comprehensive study on the reconfiguration of each regime component and their interactions would be useful for identifying barriers and stimuli for regime transformation.

Acknowledgements We gratefully acknowledge the interviewees for providing useful information. The field trip was financially supported by the RiBaGo project.

References

An DX (2009) Initial exploration and perspective of the integrity of river ecosystem functions. EEDU. http://www.eedu.org.cn/Article/es/envir/stratage/200902/33639.html. Accessed 15.April 2012

Arentsen MJ, Bressers HTHA, O'Toole LJ (2000) Institutional and policy responses to uncertainty in environmental policy: a comparison of Dutch and U.S. styles. Pol Stud J 28(3):597–611

Cai XM (2008) Water stress, water transfer and social equity in Northern China-implications for policy reforms. J Environ Manag 87(1):14–25. doi:10.1016/j.jenvman.2006.12.046

CAS (2005) Solutions and suggestions on alleviating the interruption of the Yellow River. Academic Division of CAS. http://www.casad.cas.cn/zxpy/ysjy/200505/t20050509_44092.html. Accessed 15.April 2012

Cenacchi N et al. (2010) Water Rights and Water Rights Trading: Option for the Yellow River Basin? Project paper. http://www.ifpri.org/publication/water-rights-and-water-rights-trading. Accessed 15.April 2012

Ding YH et al (2007) China's national assessment report on climate change (I): climate change in China and the future trend. Adv Clim Chang Res 3(Suppl):1–5

Erdos Government (2009) Circular on the implementation method of the second run of Yellow River water use rights exchange in the Erdos City

Folke C, Hahn T, Olsson P, Norberg J (2005) Adaptive governance of social-ecological systems. Annu Rev Environ Resour 30:441–473. doi:10.1146/annurev.energy.30.050504.144511

Geels F (2004) Understanding system innovations: a critical literature review and a conceptual synthesis. In: Elzen B, Geels FW, Green K (eds) System innovation and the transition to sustainability: theory, evidence and policy. Edward Elgar Publishing, Cheltenham, pp 19–47

Gunderson LH, Carpenter SR, Folke C, Olsson P, Peterson G (2006) Water RATs (Resilience Adaptability and Transformability) in lake and wetland social-ecological systems. Ecol Soc 11(1)

Haas PM (1992) Introduction: epistemic communities and international policy coordination. Int Organ 46 (1):1–35

Heilmann S (2008) Policy experimentation in China's economic rise. Stud Comp Int Dev 43:1–26. doi:10.1007/s12116-007-9014-4

Hou QL (2011) The story at the Yellow River estuary. http://www.mwr.gov.cn/ztpd/2011ztbd/xzhhksl/zpzs/201105/t20110527_282559.html. Accessed 15.April 2012

Hu JL, Ge YX, Zhou YX (2005) Study on water use rights market and allocation of water resources in the agricultural sector. Chinese Agriculture Publisher, Beijing (in Chinese)

Kingdon JW (2003) Agendas, alternatives, and public policies. Longman, London

Li GY (2004) The ultimate goal of Yellow River management is "maintaining the health of the Yellow River". http://www.chinawater.net.cn/Journal/cwr/200401/02.htm. Accessed 15.April 2012

Li GY (2010) Thoughts about the water use rights exchange. Sci Inf Yellow River Manag 1:12–15

Lin W, Deng WH (2003) Expert calls for leaving "live water" for the Yellow River. http://news.xinhuanet.com/st/2003-04/06/content_818311.htm. Accessed 15.April 2012

Linderman S (2006) Water regime formation in Europe: A research framework with lessons from the Rhine and Elbe river basins. Paper prepared for the German-Israeli-Palestinian research project "From conflict to collective action. Institutional change and management options to govern trans-boundary watercourses"

Liu CM, Xia J (2004) Water problems and hydrological research in the Yellow River and the Huai and Hai River basins of China. Hydrol Process 18:2197–2210

Ma XQ, Han JM, Chang YK (2007) Research on the Institutional Change of Water Rights of the Yellow River. Res Chinese Econ Hist. 1

MWR (2004) The Guideline for piloting water use right exchange in the Inner Mongolia and Ningxia part of the Yellow River. http://www.nmgslw.gov.cn/info/infoView.jsp?idcontent=2231. Accessed 15.April 2012

MWR (2006) China Water Resource Bulletin. http://www.chinawater.net.cn/cwsnet/CWSArticle_View.asp?CWSNewsID=29585. Accessed 15.April 2012

MWR (2007) The YRCC actively promotes WWP and the detailed distribution of TAC. http://www.mwr.gov.cn/slzx/sjzsdwdt/200711/t20071119_133605.html. Accessed 15.April 2012

Ni JR, Qian ZH (2002) Discussion about the "functional cut-off" of the Yellow River. Sci China 32(4):496–502

Olsson P, Gunderson LH, Carpenter SR, Ryan P, Lebel L, Folke C, Holling CS (2006) Shooting the rapids: navigating transitions to adaptive governance of social-ecological systems. Ecol Soc 11(1)

Pahl-Wostl C (2007) Transition towards adaptive management of water facing climate and global change. Water Res Manag 21(1):49–62. doi:10.1007/s11269-006-9040-4

Pahl-Wostl C (2009) A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. Glob Environ Chang 18:354–365. doi:10.1016/j.gloenvcha.2009.06.001

Shao WW et al (2009) Water resources allocation considering the water use flexible limit to water shortage—a case study in the Yellow River basin of China. Water Resour Manag 23(5):869–880. doi:10.1007/s11269-008-9304-2

Van der Brugge R (2009) Transition dynamics in social-ecological systems: the case of Dutch water management. Dissertation, Erasmus University of Rotterdam

Walker B, Holling CS, Carpenter SR, Kinzig A (2004) Resilience adaptability and transformability in social-ecological systems. Ecol Soc 9(2)

Wang SC (2003a) Resource-oriented water management: towards harmonious co-existence between man and nature, 1st edit. China Water Power Press, Beijing

Wang YH (2003b) Improving allocation system of the Yellow River. Yellow River 25(4):19–22

Wang YH (2003c) Water dispute in the Yellow River basin: challenges to a centralized system. China Environ Ser 6:94–98

Wang YH (2005) Evaluation on no flow depletion of the yellow river for five years running and depletion prevention. Yellow River 27(4):1–4

Wang YH (2009) Implications and Prospect of water rights transfer in the Yellow River Basin. hwcc. http://www.nsbd.com.cn/NewsDisplay.asp?Id=210041

Wang et al (2008) Water Right Institution and Strategies of the Yellow River Valley. Water Resour Manag 22 (10):1499–1519. doi:10.1007/s11269-008-9239-7

Wang JX, Zhang LJ (2010) Water Policy, Management and Institutions: Role in Pro-Poor Water Allocation in the Yellow River Basin. Report submitted to IFPRI for the Challenge Program on Water and Food Yellow River Basin Focal Project

Water Entitlements and Trading Project (WET) (2006) Report on the Development of Water Rights and Trading in the People's Republic of China

Wu CH, Wang H (2007) China: seeking meaningful decentralization to achieve sustainability. In: Breton A (ed) Environmental governance and decentralisation. Edward Elgar Publishing, Cheltenham

Xi ZG (2010) The movement of industry to West facing challenges posed by the Yellow River. Phoenix Weekly (34). http://blog.sina.com.cn/s/blog_5db34b3b0100of82.html

Xia C, Pahl-Wostl C (in review). Understanding Transition in flood management of Yangtze River Basin—an in-depth case study of Dongting Lake area at the middle Yangtze

Xia XH et al (2009) Incorporating eco-environmental water requirements in integrated evaluation of water quality and quantity—a study for the Yellow River. Water Resour Manag 23:1067–1079. doi:10.1007/s11269-008-9315-z

Xie J et al. (2009) Addressing China's Water Scarcity: Recommendations for Selected Water Resource Management Issues. World Bank Publications

Xu ZX et al (2002) Sustainability analysis for Yellow River water resources using the system dynamics approach. Water Resour Manag 16:239–261. doi:10.1023/A:1020206826669

Xue YP (2005) Environmental water demand and the initiative to keep the yellow river healthy: the Chinese approach. Environ Flow 2(1)

YRCC (2001) The Yellow River Water Resource Bulletin. http://www.mwr.gov.cn/zwzc/hygb/szygb/glyszygb/200101/t20010101_29462.html . Accessed 15.April 2012

YRCC (2002) Short-term plan of key management and development of the Yellow River. The Yellow River Publisher, Zhengzhou

YRCC (2008a) The construction and practice of water use rights exchange in the Yellow River. The Yellow River Publisher, Zhengzhou

YRCC (2008b) Management and diversion of water resources in the Yellow River. The Yellow River Publisher, Zhengzhou

YRCC (2009) The Yellow River Water Resource Bulletin. http://www.yellowriver.gov.cn/other/hhgb

Zhao JS et al (2009) Evaluation of economic and hydrologic impacts of unified water flow regulation in the Yellow River basin. Water Resour Manag 23:1387–1401. doi:10.1007/s11269-008-9332-y

Zheng TH, Xu CX, Xu C (2006) Study on water use right allocation and exchange. Hohai Publisher, Nanjing