A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes

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A R T I C L E   I N F O

A B S T R A C T

Governance failures are at the origin of many resource management problems. In particular climate change and the concomitant increase of extreme weather events has exposed the inability of current governance regimes to deal with present and future challenges. Still our knowledge about resource governance regimes and how they change is quite limited. This paper develops a conceptual framework addressing the dynamics and adaptive capacity of resource governance regimes as multi-level learning processes. The influence of formal and informal institutions, the role of state and non-state actors, the nature of multi-level interactions and the relative importance of bureaucratic hierarchies, markets and networks are identified as major structural characteristics of governance regimes. Change is conceptualized as social and societal learning that proceeds in a stepwise fashion moving from single to double to triple loop learning. Informal networks are considered to play a crucial role in such learning processes. The framework supports flexible and context sensitive analysis without being case study specific.

First empirical evidence from water governance supports the assumptions made on the dynamics of governance regimes and the usefulness of the chosen approach. More complex and diverse governance regimes have a higher adaptive capacity. However, it is still an open question how to overcome the state of single-loop learning that seem to characterize many attempts to adapt to climate change. Only further development and application of shared conceptual frameworks taking into account the real complexity of governance regimes can generate the knowledge base needed to advance current understanding to a state that allows giving meaningful policy advice.

1. Introduction

The sustainable management of environmental resources has been a topic of continued concern. Critical voices have argued for major paradigm shifts in management since prevailing environmental resources management approaches have been mechanistic and technocratic largely neglecting complexity and the human dimension (Holling and Meffe, 1996; Ludwig, 2001; Gleick, 2003; Pahl-Wostl, 1995, 2007a,b,c). This ongoing debate has been fuelled by prospects of climate and global change which render the conditions under which management has to perform increasingly unpredictable. Globalization exhibits breath taking dynamics and leads to large-scale changes with unprecedented speed. In particular climate change and the concomitant increase of extreme weather events have exposed vulnerability of prevailing resource management regimes (e.g. Bates et al., 2008 on climate and water; Pahl-Wostl, 2007a). It has also become evident that many problems are not primarily associated with the resource base but have to be attributed to governance failures.

Governance failures are manifold and affect both developing and industrialized countries albeit in different ways. In many developing countries corruption and the absence of civil society, a lack of efficiency and effectiveness of existing governance structures pose problems for any kind of development—not only for resource governance. Basis human needs are not satisfied for large parts of the population. In contrast, many industrialized countries suffer from over-regulation by rigid bureaucracies, sectoral fragmentation and a prevailing dominance of economic over environmental considerations. Despite starting from quite different initial conditions the resource governance challenge displays similarities: how to implement sustainable resource governance and management regimes that are resilient to global and climate change? Being resilient implies that basic functions of a regime are sustained despite of short-term disturbance or long-term societal or environmental changes.

Correspondingly attention has shifted towards an improvement of our understanding of the requirements for sustainable resource governance in changing environments (Dietz et al., 2003; Folke

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et al., 2005; Pahl-Wostl, 2007a,b; Armitage, 2008). Adaptive governance and social learning have been identified as essential for governing social-ecological systems during periods of abrupt change (Folke et al., 2005; Pahl-Wostl, 2007b). The ability of governance systems to deal with uncertainty and surprise is an essential requirement for their sustainability in times of increasing uncertainty due to climate and global change. However, our knowledge about the relationship between characteristics of resource governance regimes and their performance and the nature of their dynamics is still quite limited.

Resource governance regimes have often evolved over long periods of time and are closely intertwined with technological infrastructure and other artefacts (e.g. Geels, 2002; Pahl-Wostl, 2007a,b; Smith et al., 2005). Co-evolutionary development and path-dependence has generated an interdependence of regime elements which is important to guarantee the functioning of a regime, and the convergence of expectations of actors. The downside of such interdependence is that it prevents change, that it generates what one may refer to as lock-in-situations, a term introduced in economics to refer to the domininance of established technologies despite inferior performance due to path-dependence (Arthur, 1994). Pahl-Wostl (2007a) even argued that resource governance regimes are based on informal guiding principles that can be summarized in the notion of a paradigm (e.g. command and control). Such a paradigm generates a kind of 'internal logic' and selective environment which excludes non-compatible approaches. A command-control regime is for example not compatible with an active involvement of stakeholders in the design of policies and management plans. These kinds of considerations have to be taken into account when addressing the dynamics of governance regimes and in particular barriers to change.

This paper responds to the resource governance challenge by developing a conceptual framework to analyse the dynamics and adaptive capacity of resource governance regimes as multi-level learning processes. Adaptive capacity is defined as the ability of a resource governance system to first alter processes and if required convert structural elements as response to experienced or expected changes in the societal or natural environment. The development of the framework is based the following assumptions derived from theoretical and empirical evidence that will be further substantiated throughout the course of the paper:

- Sustainable management of environmental resources cannot be realized unless current resource management regimes undergo a transition towards more adaptive and integrated resource governance (Pahl-Wostl, 2007a,b; Folke et al., 2005).
- Addressing the challenges posed for resource governance is hampered by serious knowledge gaps and the lack of a sound conceptual base to understand learning and change in multi-level governance regimes (Pahl-Wostl, 2007b; Young, 2007; Ostrom, 2001, 2008).
- More emphasis has to be given to network governance and processes of social and societal learning (Armitage et al., 2008; Folke et al., 2005; Pahl-Wostl et al., 2007a,b).
- Resource management is a political process and the implementation of all policies is to some extent an experiment. Political processes are emergent phenomena in complex adaptive systems (Duit and Galaz, 2008; Harrison, 2006; Pahl-Wostl, 2007a,b). Approaches towards improving the analytical and normative understanding of resource governance regimes have to take this into account (Ingram, 2008; Pahl-Wostl, 2007a).

Elucidating the characteristics and performance of resource governance and processes of change towards more adaptive and sustainable regimes requires a framework of intermediate complexity. On the one hand, too generic and simplistic approaches will hardly be able to address the complexity of real governance regimes. Panaceas have proven to be weak in their explanatory power and not very useful or even detrimental for policy advice (Ostrom, 2007; Ingram, 2008). On the other hand, too specific and detailed analyses will hardly lead to insights that can be generalized across individual case studies. A framework of intermediate complexity should support context sensitive analysis without being case specific and thus not transferable. What is required may be called a diagnostic approach taking into account complexity in a systematic fashion (Pahl-Wostl, 1995; Ostrom, 2007; Young, 2007).

A diagnostic approach towards governance has been promoted in the context of designing institutions for sustainable governance of human-environment interactions (Ostrom, 2007; Young, 2008). Young (2008) put forward a set of principles for the "diagnosis" of institutional problems based on experience from research in the IDGEC program. Ostrom (2007) developed a kind of ontology by organizing variables of interest in the study of social-ecological system in a nested, multitier framework. Both approaches have in common that they are flexible and the analyst can choose and tailor his/her inquiries according to the needs of the issues under consideration. It is also evident that such an approach has to adopt a systemic perspective to embrace complexity and the wealth of interactions characterizing governance regimes.

The framework introduced in this paper provides a coherent approach to analysing the structural characteristics of a governance regime, the nature of policy and learning processes and how structure is influencing processes and how processes lead to a change in structure. The paper is organized as follows. In Section 2 a profound reasoning is given for the choice of important elements to characterize a governance regime. Section 3 introduces a concept for multi-level and multi-loop learning. Differences expected for different kinds of learning processes are expressed in terms of the elements of governance regimes introduced in Section 2. Section 4 highlights the importance of informal networks that are considered to be crucial to support change. Section 5 summarizes first insights from empirical analyses in water governance regimes.

2. Important elements of governance regimes

The distinction between resources management and governance is not always very clear. Sometimes management and governance are even used as synonyms what is clearly not appropriate. 'Resources management' refers to the activities of analysing and monitoring, developing and implementing measures to keep the state of a resource within desirable bounds. The notion of 'resource governance' takes into account the different actors and networks that help formulate and implement environmental policy and/or policy instruments.

Governance embraces the full complexity of regulatory processes and their interaction. This is reflected in the definition of water governance by UNDP:

> "*Water governance refers to the range of political, social, economic and administrative systems that are in place to regulate development and management of water resources and provisions of water services at different levels of society (UNDP, 2000)*"

Analysing the dynamics of such multi-level and complex governance systems provides a considerable challenge. However, the major conceptual frameworks in the social sciences of interest to resource governance studies (i.e. regime theory in political sciences, game theory, new institutional economics) are quite weak in their ability to analyse the complex, context dependent dynamics of governance regimes (Harrison, 2006; Young, 2007;

Ostrom, 2008). Most governance analyses focus on static descriptions and embrace only a part of the processes of importance. Further, in contrast to traditional notions of government the analytical distinction between those actors who govern and those who are governed is not valid anymore which is adding an additional layer of complexity (Mayntz, 2006). The evolution in the discourse from "government" to "governance" implies a change in thinking about policy processes. The notion of government as the single decision making authority, where state authorities exert sovereign control over the people and groups making up civil society, has been widened by the notion of multi-level, polycentric governance where many actors in different institutional settings contribute to policy development and implementation (Mayntz, 2006). 'Governance' takes into account the increasing importance of modes of governing, where non-state and private corporate actors and networks participate in the formulation and implementation of public policy or develop policy instruments that co-exist with existing government policy processes (Rhodes, 1997). Governance encompasses coordination and steering processes to influence behaviour by formal and informal institutions (Scharpf, 1997). Governance regimes are thus characterized by self-organization, emergence and diverse leadership. What is yet lacking is a profound understanding of what "steering" and "managing change" might imply in such diffuse, complex and multi-level networks, how all these complex processes act in concert and under which conditions they lead to a sustainable governance of environmental resources.

In the scientific literature one finds a whole range of different approaches to conceptualize governance. Treib et al. (2005) classified the major streams according to whether governance is seen as belonging primarily to the realms of politics, polity or policy. Related to the politics dimensions governance emphasizes the way of policy making, how different preferences are translated to effective policy choices and different interests are transformed to unitary action (Kohler-Koch, 1999). Other governance approaches more closely related to the polity dimension focus on an institutionalist approach and conceive of governance as system of rules that shape the action of actors (e.g. Rosenau, 1995; Ostrom, 2005). Finally governance may also be defined as modes of political steering and refer thus primarily to the policy dimension (e.g. Héritier, 2002). It may be useful from an analytical perspective to make a distinction between these dimensions. However, such distinction may not do justice to the complexity of real-world governance regimes. It may be virtually impossible to determine what is the dependent and what is the independent variable. In particular the politics and polity dimensions cannot be separated. In their analytical approach of an actor centred institutionalism Mayntz and Scharpf (1995) combine an actor centred and an institutionalist approach. An encompassing approach to resource governance as presented by the UNDP definition on water governance embraces all dimensions. More and more scholars promote an encompassing concept of governance doing justice to the complexity of societal dynamics and as a concept bridging social science disciplines (e.g. Kooiman, 2000; Benz, 2004; Schuppert, 2006). The approach presented here for resource governance follows similar lines of reasoning. To deal with the complexity of governance systems in more systematic fashion the following four dimensions are introduced as base for analysing the characteristics of environmental governance regimes:

- Institutions and the relationship and relative importance of formal and informal institutions.
- Actor networks with emphasis on the role and interactions of state and non-state actors.
- Multi-level interactions across administrative boundaries and vertical integration.

- Governance modes—bureaucratic hierarchies, markets, networks.

In the following these dimensions are elaborated in more detail.

2.1. Institutions—formal and informal

Institutions are used here according to the convention in institutional analyses in the social sciences to denote rules governing the behaviour of actors (e.g. North, 1990; Scott, 2001). Institutions do not refer to organizations or physical structures. Formal and informal refer to nature of processes of development, codification, communication and enforcement. Formal institutions are linked to the official channels of governmental bureaucracies. They are codified in regulatory frameworks or any kind of legally binding documents. Correspondingly they can be enforced by legal procedures. Informal institutions refer to socially shared rules such as social or cultural norms. In most cases they are not codified or written down. They are enforced outside of legally sanctioned channels.

Important for a governance regime is the relative strength of formal and informal institutions, respectively. Helmke and Levitsky (2004) derived a typology for the relationship between formal and informal institutions based on and the compatibility of goals and the effectiveness of formal institutions. Formal institutions may be either effective or ineffective. A measure for the degree of effectiveness of formal institutions is for example given by the importance of corruption[1] (e.g. measured by the Corruption Perception Index). The goals of informal and formal institutions may be either compatible or conflicting. In an ideal case formal institutions are effective and the goals of formal and informal institutions are compatible. In this case the two kinds of rule systems complement each other and efficiency and effectiveness of governance processes are increased. In a more problematic case formal institutions are ineffective and formal and informal institutions follow conflicting goals. In this case the two kinds of rule systems compete with each other. Such a governance regime would most likely be characterized by a high degree of corruption, intransparent decision processes and dominance of established power structures. This is the case in many developing countries where strong environmental regulation exists on paper but is not at all implemented in practice. It is important to take these distinctions into account to understand the full nature of potential governance failures and drivers and barriers for change and the role of informality in these processes.

As outlined in the introduction resource governance regimes are assumed to be characterized by a dominant paradigm (Pahl-Wostl, 2007b). The importance of a paradigm and associated belief structures can be better captured if the characterization of institutions is refined. A further distinction between formal and informal institutions is introduced following Scott (2001) who distinguishes between three pillars of institutions: regulative (what is formally allowed and what is not allowed), normative (what is right and what is wrong judged by societal standards), cultural-cognitive (what is thinkable and what is unthinkable). These different categories are also associated with different kinds of dynamics regarding change.

- Regulative institutions can be identified with formal legal structures, regulatory frameworks, formalized professional rules of good practice as typically codified in professional handbooks. Introduction of new regulative institutions is associated with

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[1] A widely accepted measure for the degree of corruption in a country and thus the effectiveness of formal institutions is the annual, Corruption Perception Index' published by Transparency International (www.transoarency.org).

high transaction costs. Hence a broader interpretation of existing institutions will most likely be the first approach for widening the scope of existing regulatory frameworks (e.g. analysis of institutional change in EU budgetary politics by Lindner, 2003).

- Normative institutions can be identified with informal societal norms, shared but not codified rules of good practice. Normative institutions reflect value structures. Contrary to regulative institutions change is not based on negotiations and formal agreements but is more gradual and emergent.
- Cultural-cognitive institutions can be identified with paradigms, mental models that strongly influence system understanding, how boundaries are delineated, the search space for problems and solutions are determined (Pahl-Wostl et al., 2007b). Similar to normative institutions change is not negotiated but enacted in shared practices.

2.2. Role of actor groups—state, non-state actors

A major characteristics of governance regimes are the diverse roles of non-state actors. The past decades have seen a weakening of influence and power of the nation state (Holton, 1998). This may be attributed to increasing globalization and to a strengthening of civil society in general. Participatory approaches have become a major pillar in environmental resources management (Berkes and Folke, 2002; Pahl-Wostl et al., 2007b). Such issue specific participation in policy development and implementation must not be in contrast to representative democracy. It rather reflects the need for new modes of governance and knowledge generation to deal with increasing uncertainty and complexity (Berkes et al., 2003; Pahl-Wostl, 2007c). Participation of interested parties can reduce uncertainties in the policy implementation process by reducing the likelihood of unexpected resistance (Newig et al., 2005). Including a broader set of stakeholders gives as well access to different kinds of knowledge which may be vital for a full assessment of a resource governance problem and for finding innovative solutions to deal with it (e.g. Berkes and Folke, 2002).

Compared to the traditional form of governmental authority and control, the roles of actors become blurred in more complex and intertwined governance regimes. Actors are involved in designing the institutions that (are supposed to) govern their behaviour. To some extent this also reduces the distinction between formal and informal institutions. Compliance to formal rules is not only enforced by sanctions as the rational actor paradigm would suggest but by embedding formal rules in actors' values and norms. Ostrom (1990) convincingly shows that user communities of a common pool resource have the capacity for self-organization and self-governance and that there are many different viable combinations between public and private. Involving actors in the design of formal institutions is expected to increase compliance and effectiveness. But this may come at the expense of decreased efficiency since participatory processes are resource consuming. Again it is an important research question how to find an appropriate balance.

2.3. Multi-level interactions

The dispersion of authority away from the central state has drawn more and more attention to the multi-level nature of governance regimes both from an analytical and a normative perspective. Even when the term of "multi-level governance" has become more popular only over the last decade, such phenomena have been subject of analyses in the political sciences much earlier. Research on federalism has explored delegation of authority from the central state to lower levels and analysed the performance of different kinds of political systems from more centralized (e.g. France) to more federal (e.g. Germany, Switzerland) structures

(Ammon et al., 1996) The influence of different levels has always been a theme in international relations studies (Welch and Kennedy-Pipe, 2004). Multi-level governance as such has become quite prominent with research on the European political system which has become characterized by a complex interaction between the European level, the nation states and regions (Hooghe and Marks, 2003). Hooghe and Marks (2003) make a distinction between type I governance related to the observed dispersion of authority to general-purpose, nonintersecting, and durable jurisdictions of limited number as in typical federal systems or and type II governance characterizing more task-specific, intersecting jurisdictions of flexible design and at many jurisdictional levels. However, this distinction remains within the realm of regulative institutions. A development of major interest for resource governance is the distinction of polycentric systems with many centres of decision making which go beyond jurisdictions and include other modes of coordination.

The notion of polycentric political systems was introduced by Vincent Ostrom already some decades ago as a system 'of many centres of decision making which are formally independent of each other' (Ostrom et al., 1961). Comprehensive treatises on polycentric governance in public policy can be found in Ostrom (1997), McGinnis (1999a,b, 2000) and Heinelt (2002). The concept has been further developed and has in recent years been extended to go beyond formal political systems (Ostrom, 2001). More generally, polycentric governance systems are defined here as complex, modular systems where differently sized governance units with different purpose, organization, spatial location interact to form together a largely self-organized governance regime. Polycentric governance systems are characterized by many degrees of freedom at different levels. Multi-level governance in polycentric systems implies that decision making authority is distributed in a nested hierarchy and does not reside at one single level, neither top (only highest level government enforcing decisions), nor medium (only states/provinces enforce decisions beneficial for their region without considering others), nor individuals with complete freedom to act or being connected in a market structure only.

From a normative point of view it is of major interest that polycentric systems are assumed to have a higher ability to adapt to a changing environment and to be less affected in their integrity by sudden changes or failure in parts of the system (Ostrom, 2001, 2005; Pahl-Wostl, 1995, 2007a,b). Arguments supporting this statement can be derived from complex adaptive systems theory. A complex adaptive system (CAS) is a complex, nonlinear, interactive system which has the ability to adapt to a changing environment (Pahl-Wostl, 1995; Levin, 1999). Such systems are characterized by the potential for self-organization, existing in a non-equilibrium environment. In a CAS, many elements interact according to certain rules of interaction. The elements are diverse in both form and capability and they adapt by changing their rules and, hence, behaviour, as they gain experience. Examples include living organisms, the nervous system, the immune system, the economy, corporations, societies, and so on. Modular system structure and decentralized control lead to higher degree of adaptiveness and robustness of a system (Pahl-Wostl, 1995; Miller and Page, 2007). Similarly theoretical ecologists have claimed a positive relationship between increasing diversity of ecological systems and increasing ability to maintain functional integrity in changing environments (Pahl-Wostl, 1995; Ludwig et al., 1997; Tilman, 1999). Polycentric and adaptive governance systems should include a certain degree of redundancy. This claim is in conflict with a short-term maximization of efficiency. It is an important research question how to strike an appropriate balance between improving efficiency by redundancy and increasing adaptive capacity by increasing redundancy.

Multi-level water governance regimes are particularly complex. To reduce problems of fit between administrative and biophysical boundaries new formal institutions have been introduced in most countries of the world following the hydrological principles. As Moss (2007) highlighted problems of fit have often been solved at the expense of problems of interplay. Problems of vertical and horizontal interplay between newly established institutions at basin scale and those organized at traditional administrative boundaries (e.g. spatial planning, agriculture) prove to be a barrier for implementing integrated management approaches and may lead to overly complex structures (Borowski et al., 2008). They are also an impediment for the adaptation to climate change which requires effective vertical coordination.

The introduction of the hydrological principle is only one of a variety of barriers to effective vertical coordination of governance levels. Innovative solutions to overcome potential barriers for vertical coordination are in high demand. Important processes connecting levels and improving vertical coordination are:

- Actors from one level (e.g. the national level) participate in decision processes at another level (e.g. the European level or basin level). Actors may thus become actively involved in the production of the rules that influence them.
- Institutions (formal and informal) produced at one level influence processes at another level. Flow of authority may be both top-down and bottom-up.
- Knowledge produced at one level influences processes at another level.

2.4. Governance modes—bureaucratic hierarchies, markets, networks

One attempt at classification is the distinction between bureaucratic hierarchies, networks and markets as the main governance modes (e.g. Thompson et al., 1991). These modes differ strongly along the dimensions of the degree of formality of institutions and the role of state versus non-state actors (Fig. 1). In bureaucratic hierarchies regulatory processes are mainly based on formal institutions and governmental actors play the dominant role. Markets are based on a combination of formal and informal institutions and non-state actors dominate. Networks are largely governed by informal institutions and both state and non-state actors may participate. The informality and high flexibility in membership makes networks so interesting for processes of learning and change (Dedeurwaerdere, 2005).

Given the complex nature of governance systems, change can be expected to be a combination of purposeful collective action

Fig. 1. Difference of governance modes of bureaucratic hierarchies, markets and networks regarding the degree of formality of institutions and the importance of state and non-state actors.

(e.g. legal regulations) and emergent phenomena resulting from self-organizing processes and interactions among a range of actors. The attention for the importance of networks in this respect has increased considerably over recent years (Kooiman, 2003; Dedeurwaerdere, 2005). In particular informal networks may be very flexible in terms of membership, role and power of actors and connections. They support learning by providing access to new kinds of knowledge and by supporting multiple ways of inter-pretation. However, networks may also be closed to outsiders. Membership may not be representative and their legitimacy of dealing with an issue of public interest may be disputed. It is also not clear who is to be made accountable for failed governance notions (Rhodes, 2000).

It is a very intriguing research question to understand how bureaucratic hierarchies, markets and networks act in concert and which kinds of governance systems support an appropriate balance between permanence and change. Absence of change results in the inability to adapt to changing circumstances triggered by internal and external events and trends. Complete absence of permanence and predictability results in the inability of actors to develop expectations, coordinate collective action and improve routines and practices. These considerations suggest that rather than a dominance of one governance mode a more diverse governance system has a higher adaptive capacity and will lead to more sustainable resource governance.

3. Dynamics of governance regimes as learning processes

The approach chosen here conceptualizes change in governance regimes as social and societal learning. It addresses processes of purposeful action and of self-organization and emergence. The distinction between social and societal is made to emphasize the importance of learning in multi-actor settings and of structural change in the governance regime as a whole.

There are multiple applications and definitions of social learning in resources management. Pahl-Wostl et al. (2007b) investigated social learning in river basin management and developed a conceptual framework to capture the essential processes of multi-level social learning. They assume social learning to be essential for developing and sustaining the capacity of different authorities, experts, interest groups and the public to manage their river basins effectively. Effectively implies that they are able to negotiate about goals and how to achieve them and to translate this into action. The focus of the conceptual approach chosen is on learning of the social entity as a whole and the emergence of properties of the actors' collective. The framework is characterized by a broad understanding of social learning that is rooted in the more interpretative strands of the social sciences. The framework revolves around processes of multi-party interactions, embedded in a specific societal and environmental structural context and leading to specific outcomes. A feedback loop between outcomes and context takes into account structural changes in a cyclic and iterative fashion. The context refers to the overall governance structure and the natural environment in a river basin. The governance structure has a strong influence on the nature of multi-party cooperation and social learning processes. Results from empirical analyses show for example that centralized political and economic systems, privatization and commercialisa-tion of environment, rigid bureaucratic systems and political secrecy and poor public access to information impedes social learning (Mostert et al., 2007; Tippet et al., 2005).

Learning is assumed to be an exploratory, stepwise search process where actors experiment with innovation until they meet constraints and new boundaries. Learning may thus have different levels of intensity and scope (Pahl-Wostl et al., 2007a,b,c). Such different levels of learning are addressed in
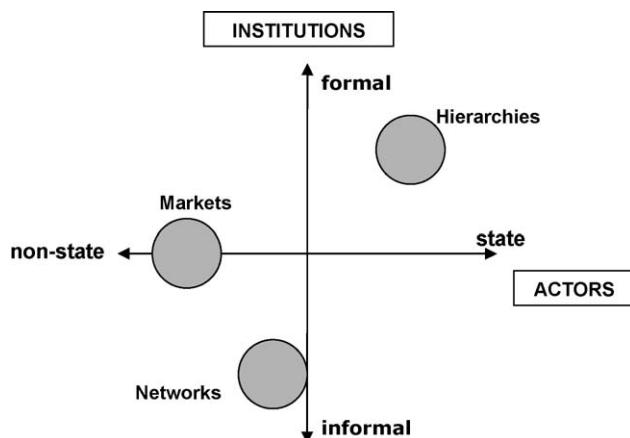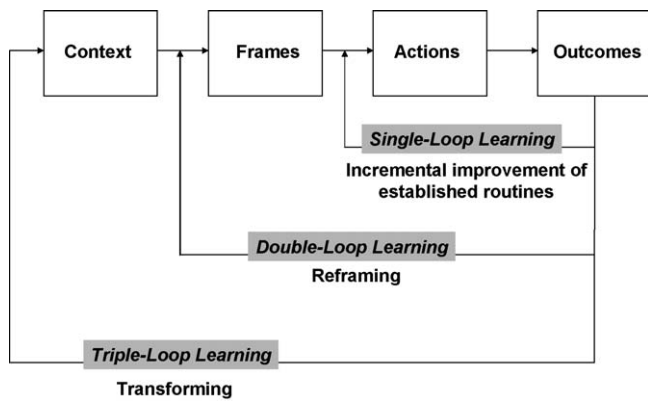
Fig. 2. Sequence of learning cycles in the concept of triple-loop learning (derived from Hargrove, 2002). Further explanation in the text.

the concept of triple-loop learning (Hargrove, 2002) developed in organizational theory (Fig. 2).

The concept of triple-loop learning has become quite popular in management theory to guide concept and practice of managing change in organizations (e.g. Hargrove, 2002). It has been derived from the even more popular concept of double-loop learning developed by Argyris and Schön (1978). The triple-loop learning concept aims at a refinement of the influence of governing variables in terms of governing assumptions and governing values. Single-loop learning refers to an incremental improvement of action strategies without questioning the underlying assumptions. Double-loop learning refers to a revisiting of assumptions (e.g. about cause–effect relationships) within a value-normative framework. In triple-loop learning one starts to reconsider underlying values and beliefs, world views, if assumptions within a world view do not hold anymore.

The distinction is phrased slightly differently by Flood and Romm (1996) who cast triple-loop learning in three kinds of questions. In single-loop learning actors question if they do things right. In double-loop learning they start to reflect if they do the right things. In triple-loop learning they call into question if rightness buttressed by mightiness and/or mightiness buttressed by rightness. This conceptualization addresses thus the importance of power to impose certain values and norms.

A multiple-loop learning concept has been applied as well in the context of collaborative learning and environmental and resource management by Armitage et al. (2008). They associated triple-loop learning with changes in governance norms and protocols.

The multiple-loop concept for learning is compelling since it takes into account the different levels that provide guidance and stability in a social system at increasing time scales for change. The direction of progress might become haphazard if individuals or organizations would revisit and change basic values and beliefs all the time. However, there would be no innovation or evolution to higher adaptive capacity if individuals or organizations never revisited basic values and beliefs. A lack of critical self-reflection is a severe constraint for societal learning and transitions to more sustainable resource governance approaches. Human beings have a confirmation bias; they search for and selectively process information confirming their beliefs (Evans, 1990). This may lead to neglecting knowledge which contradicts dominating assumptions and thus to a lack of recognizing potential threats and needs for change. Hence understanding which kind of processes support moving beyond single-loop learning is essential.

The three levels of learning are now translated to corresponding changes in resource governance regimes. They are assumed to represent the following kinds of processes.

Single-loop learning refers to a refinement of actions to improve performance without changing guiding assumptions and calling into question established routines. Incremental changes in established practice and action aim at improving the achievement of goals. This phase might also include a first improvement of the capacity to make and implement collective decisions. In the development of climate change adaptation policies actors may request for example an improvement of regional climate change models in order to know how much to increase the height of dikes or the size of reservoirs.

Double-loop learning refers to a change in the frame of reference and the calling into question of guiding assumptions. Reframing implies a reflection on goals and problem framing (priorities, include new aspects, change boundaries of system analysis) and assumptions how goals can be achieved. Social learning processes are essential. Actors explore the full space of reframing within structural constraints. This might lead to changes in the actor network characterizing the resource governance regime. Improvement is achieved by experimenting with innovative approaches and new kinds of measures. In dealing with climate change in flood management for example this might imply that one takes into account the relocation of dikes, retention areas and restoration of floodplains rather than simply increasing the height of dikes. However, a widespread implementation of innovative approaches might be hindered by structural constraints of the context which stabilizes the dominant frames.

Triple-loop learning refers to a transformation of the structural context and factors that determine the frame of reference. This kind of societal learning refers to transitions of the whole regime. (e.g. change in regulatory frameworks, practices in risk management, dominant value structure). Transforming requires recognition that paradigms and structural constraints impede an effective reframing of resource governance and management practices. Learning processes involve actors that go far beyond the established resource governance regime. Transformation implies a change in paradigm and in the end also in underlying norms and values. The structural change will lead to a transition of actor networks where new actor groups come into play, boundaries and power structures are changed, new regulatory frameworks are introduced. In dealing with climate change in flood management this could imply a shift towards integrated landscape planning and robust action rather than optimal adaptation strategies. This might include adopting systemic indicators as strategic goals such as an increase in the resilience and adaptive capacity of the system.

Many kinds of double-loop learning can only be effective if accompanied by triple-loop learning since the dominating frame of reference is often strongly influenced by the structural context and effective reframing may not be possible. It is assumed that social learning proceeds in a stepwise fashion moving through the phases of single to double to triple-loop learning. Since higher levels of learning are associated with higher costs it is plausible to expect a succession where the next higher level is entered only when constraints at a lower level are encountered. The structure agency approach (Giddens, 1984) argues that change relates to a reproduction and reinterpretation of structure by agency. This also supports an iterative and stepwise multi-level approach towards learning.

Table 1 summarizes a succession of changes that would be expected in resource governance regimes for the different levels of learning. The comparison is based on the characteristics of governance regimes introduced in Section 2. Uncertainty is included as own category due to the importance of the handling of uncertainty for integrated and adaptive governance approaches. Table 1 pulls together the arguments made in Sections 2 and 3. The statements have largely to be regarded as hypotheses derived from conceptual and theoretical considerations with yet limited

Table 1
Characterization of changes in governance regimes expected for single, double and triple-loop learning based on the categories introduced in Section 2.

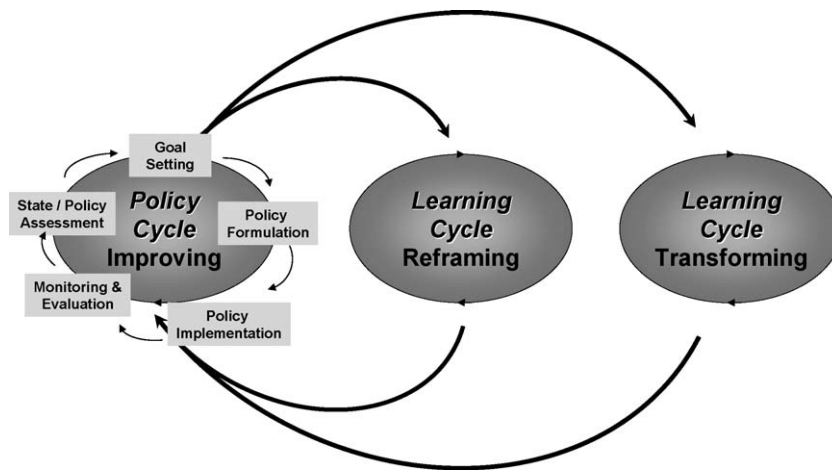|	Single loop	Double loop	Triple loop
Institutions—general	No calling into question of established institutions, signs of unilateral reinterpretation	Reinterpretation of established institutions by many parties	Established institutions changed and/or new institutions implemented
Regulative institutions	Existing regulations are strictly followed and used to justify established routines	Regulatory frameworks identified as major constraints for innovation	Formal substantial changes in regulatory frameworks, new policies implemented
	New by-laws and interpretations of existing law to accommodate exceptions	More juridical conflicts about rule interpretation	Institutional change towards more flexible regulations that leave room for context specific implementation. More process regulations
		Exemptions allowing innovative approaches and experimentation	
Normative institutions	Established norms are used to justify prevailing system Relying on codes of good practice	Established norms and routines are called into question	Change which can be identified in public discourse and new practices
Cultural-cognitive institutions	Discourse remains in established paradigms that are refined.	New ideas emerge beyond isolated groups	Discourse dominated by new paradigm (media, political debate, public hearings, scientific conferences)
	Radical alternatives clearly dismissed.	Strong arguments about alternative views—"ideological" debates	Powerful representatives of "main-stream" argue in new paradigm
Uncertainty	Uncertainty used to justify non-action	Uncertainty accepted and perceived as opportunity in processes of negotiations and reframing	Uncertainty discourse emphasizes different perspectives and world views
	Activities to reduce uncertainties. Reliance on science to find the truth/a solution	Existence of different perspective and world views explicitly acknowledged	New approaches to manage uncertainty (e.g. participatory scenario development) and risk (e.g. risk dialogues, robust action) are implemented with corresponding efforts to change structural constraints
	Discourse focuses on technical approaches to dealing with uncertainty with goal to improve predictive capabilities	Established approaches to managing uncertainty and risks are called into question	Conscious decision-taking under (irreducible) uncertainty with the prospect of adapting the measures when necessary
Actor network	Actors remain mainly within their networks—communities of practice	Explicit search for advise/opinion from actors outside of established network (e.g. invitation to meetings)	Changes in network boundaries and connections
	Established roles and identities are not called into question	New roles emerge—e.g. facilitators in participatory processes Arguments about identify frames— e.g. what does it mean to be an "engineer" Boundary spanners of increasing importance that start to connect different networks—communities of practice	New actors groups and roles have become established Changes in power structure (formal power, centrality—new actors in centre) Identity frames/roles get blurred/ less important, rather joint approaches than isolated performance according to one's role
Multi-level interactions	Vertical coordination in established patterns— e.g. increased regulation from the top level Pattern of flow of authority (by institutions) does not change. Mainly uni-directional	Increased informal knowledge exchange between levels Informal coordination groups to improve exchange in planning processes established	Formalized participation of actors at different levels Established practices of knowledge exchange across levels More polycentric structures and balance between bottom-up and top-down approaches
Governance mode	No change in the relative dominance of governance types	Other than dominant governance types start to become more visible and dominant governance type called into question (e.g. discussion of market based instruments if absent before, introduction of participatory approaches, emergence of bottom-up participatory processes, argument about dominance of one type—bureaucratic hierarchies or privatization)	New governance types implemented, established governance types substantially changed
	Improvement of performance within established governance modes	Informal networks shaping discourse and supporting experimental innovations become more prominent	More diverse governance structures– less dominance of one type Learning networks challenging dominating structural assumptions become effectively connected to and influence established policy arenas

Fig. 3. The concept of triple-loop learning applied to governance regimes. It is assumed that different kinds of learning also require a change in the composition of the actor network and in the institutional setting.

validation by empirical data. The nature of change is addressed from a general perspective. Where appropriate the specific changes expected for a transition from a 'command and control' towards more integrated and adaptive regimes (according to Pahl-Wostl, 2007a,b; Pahl-Wostl et al., 2007c) are included.

It remains to provide more empirical evidence to confirm the nature of different levels of learning and in particular their importance for adaptive capacity and change of a governance regime. The changes listed in Table 1 can be used to develop operational indicators that allow assessing the degree of learning in policy processes. This has been applied to analyse the degree of innovation observed in the development of adaptation strategies for climate change and the characteristics of governance regimes that support higher levels of learning (Huntjens et al., 2008, in review). This will be elaborated in more detail in Section 5. It is evident from Table 1 that double-loop learning requires settings that support informal discourse and social learning and thus reframing (see Pahl-Wostl et al., 2007b for details on the nature of social learning). However, such social learning may remain at the level of non-binding discourse without leading to major structural changes unless appropriate processes exist that support extension of actor network, codification of new routines and practices or formalization of new rules. The next section elaborates the role of network governance in this respect.

4. The role of learning processes in informal networks

Table 1 already highlights the importance of informal networks for double and triple-loop learning. In particular, network governance has the characteristics to support innovation and social learning. Empirical evidence suggests indeed that formation of informal networks in early stages of change is essential. The importance of such adaptive networks (Nooteboom, 2006) or shadow networks (Olsson et al., 2006) has been documented in empirical studies. Key leaders and shadow networks can prepare a system for change by exploring alternative system configurations and developing strategies for choosing among possible futures. Successful transitions in Human-Technology-Environment-Systems often rely on epistemic and shadow networks to provide novel ideas and ways of governance (Gunderson, 1999; Olsson et al., 2006).

According to Nooteboom (2006) adaptive networks are self-organizing groups of policy makers who enable joint fact finding and visualizing a direction towards improvement. These policy-makers combine two capabilities. First they are influential in, and have knowledge about, different power networks. Secondly they

try to break away from the existing policies in those power networks and develop a joint understanding about new, more effective policies in these informal adaptive networks.

To depict such dynamics in an analytical framework a distinction is made between established and formalized policy networks and adaptive and informal learning networks as represented in Fig. 3. It is assumed that interactions in formal policy cycles are mainly restricted to single-loop learning. Informal learning processes are required to support double-loop or even triple-loop learning.

The policy cycle is used in the sense of an analytical devise not as a strictly normative model (Pahl-Wostl et al., 2007a,c). Despite fundamental critique the policy cycle model has encountered (e.g. Nacurama, 1987; Sabatier, 1999) at least a distinction of different phases in such a cycle seems to be useful. Some structuring is required in order to develop and implement any policy or management plan. Management without measurable goals or evaluation if the goals are achieved is quite meaningless.

Even when the distinction of policy and learning cycles made in this paper may seem a bit arbitrary on first sight it does not only serve analytical purposes but emphasizes the need to pay due credit to informal settings. In formalized settings characterizing the policy cycle actors mainly engage in bargaining rather than open innovative discourse. They defend their entrenched positions. Also no resources (time, money) are available for experimenting and visioning. This poses severe constraints to enduring and effective higher levels of learning.

When does a process now qualify to be called a "learning cycle" to support double and triple-loop learning? The following conditions are a set of normative criteria to make a distinction (Folke et al., 2005; Pahl-Wostl, 2007b; Nooteboom, 2006).

1. It must be an at least partially informal network of actors with regular meetings. Informal implies that rules for the group (boundaries—who is involved and what is included in the analysis open; leadership is allowed to emerge; rules how the group operates are negotiable, etc.) are not formally prescribed and that the mandate is open and the results not immediately formally binding.
2. It is an issue specific network and activities—formed to deal with a specific problem and is open and willing to explicitly experiment with a range of alternatives approaches.
3. The network qualifies as a community of practice (sensu Wenger, 1998) with joint and shared practices and tangible products. This way it develops an identity, history and a body of shared knowledge which goes beyond individuals participating in it.

Purely informal networks typically develop in a bottom-up process as a kind of shadow network that has no formal link at all to the formal policy and management cycle. The opposite would be a formalized negotiation process in a trans-boundary river basin commission with the goal to agree on a formal treaty to be signed by all countries. Of particular interest are the linkages between policy and learning cycles and their influence on the learning process and the effectiveness of its outcomes. In shadow networks these linkages are very weak. This poses a certain dilemma. The more autonomous and informal these cycles, the higher is their ability to self-organize and support innovation and creative thinking. At the same time their influence on policy and real implementation is weak and it may take years until a "window of opportunity" (sensu Kingdon, 1992) arises.

An interesting example for such a shadow network is given by the 'Living Tisza Alliance' in Hungary (Sendzimir et al., 2007). The Tisza, a major tributary of the Danube, is a highly regulated river. Most of the original floodplains and the diversity of the landscape and livelihoods of local people has been lost. Large parts of the region along the river count nowadays among the poorest regions in Hungary. The incidence of severe flooding events has increased over the past decade. The shadow network has its roots in a movement that established itself as response to a number of disastrous flooding and pollution events in the 90ies. It developed innovative ideas about a more integrated and sustainable land-scape management. Sendzimir et al. (2007) describe this as a newly 'emerging paradigm "Live in Harmony with the River" with Landscape Productivity in contrast to the conventional paradigm "Protect Landscape from the River" with Agricultural Intensity. In recent years the political climate became more receptive to new ideas. The shadow network had some success in getting their ideas to the national political level and in being able to start smaller pilot projects. These linkages were all informal mainly based on individual contacts. In the most recent past the more favourable climate seems to have changed again most likely due to a dominance of different political streams and the loss of an influential individual who served as a strong link into the policy cycle (Sendzimir and Flachner, personal communication).

The example illustrates that a closer link to formal policy processes might be desirable to increase the effectiveness of learning. Weak links are provided by actors who participate in both networks and may act as knowledge carriers. A stronger link is provided if these actors have a formal mandate. One may even think of learning cycles as policy instruments started and triggered from within the formal policy network. But again it is an intriguing research question to analyse the appropriate balance between strengthening the linkages between policy cycles and learning cycles without destroying the capacity to innovate and learn of the latter.

5. Some insight from analysing water governance

Practice in water management and governance has tradition-ally been characterized by a command-and-control paradigm and has not been very supportive of learning approaches (Gleick, 2003; Pahl-Wostl, 2007a,c). This paradigm has lead to quite rigid regulations, large-scale technology, dominance of expert knowl-edge, technical approaches to risk management and engineering practices of optimal design under predictable conditions where uncertainties can at least be quantified by probability distribu-tions. What may have served well in the past to provide technical solutions to pressing problems e.g. of pollution seems to be not suitable to deal with challenges of the present and the future. Over the past decade one observes at least in discourse a fast increasing number of claims for a paradigm shift (Pahl-Wostl et al., 2006, in review). Climate change has accelerated the search for more adaptive and integrated approaches. However, one may argue that learning has if at all entered the stage of double-loop learning. Structural constraints inherent in the legacy of a management tradition based on a 'command and control' paradigm provide major barriers of change (Gleick, 2003; Pahl-Wostl, 2007a). Water governance has traditionally been centralized with narrow stakeholder participation and a dominance of governmental actors. Bureaucratic hierarchies, the once prevailing governance mode have partly been replaced by market based approaches during the privatization boom with quite limited success (Finger and Allouche, 2001; Ingram, 2008). In most countries one encounters highly regulated systems. An expert culture based on technological solutions to narrowly defined problems has lead to a fragmented understanding and lack of integration of information sources that are proprietary (Timmerman and Langaas, 2005; Pahl-Wostl, 2007a). Important barriers to change lie in the inertia of institutions, resistance to changes in power structures and costs (perceived) to be associated with a transformation (Pahl-Wostl, 2006, 2007a).

The inertia of the system is reflected in the practice of implementation of the European Water Framework Directive (WFD) which is in principle an innovative and flexible policy framework which responded to perceived short-comings of past European water policy. The WFD which entered into force 2000 has at its major goal to achieve 'good status of all European waters by 2015'.[2] It is innovative since it integrates a previously quite fragmented regulatory landscape of very specific Directives. The WFD leaves room for the member states to adapt the implementa-tion to the national and basin context. It prescribes the involvement of the public and stakeholders in the development of management plans. And it foresees implementation in several cycles where progress is monitored and measures can be improved. However, implementation of the Directive proceeds in general in quite a traditional way. Complexity and uncertainty are not fully addressed but rather the view of uncertainties as problems that need to be reduced prevails (Galaz, 2005; Isendahl et al., 2008). Constraints are not given by the European regulatory framework itself but rather by established practice linked to cognitive-cultural institutions and the dominating water govern-ance and management paradigm and national legislation. The structural change needed for a paradigm shift is slow and has not yet reached the multi-level water governance regime at large. Nevertheless, one observes some promising signs of change partly accelerated by prospects of climate change and countries in Europe differ.

Exploratory analyses based on expert judgement have been conducted in a number of case studies European and non-European countries to investigate the relationship between (change in) structural characteristics of a water governance regime and different levels of learning (Huntjens et al., in press; Huntjens et al., 2008). Learning was analysed with respect to the response to climate change and the development of adaptation measures. In one study different levels of learning were identified by developing operational indicators of the processes of change summarized in Table 1 (Huntjens et al., 2008, in review). The results of comparative analyses identified integrated cooperation structures (including non-governmental stakeholders, governments from different sectors and different hierarchical levels), and advanced information management (including joint/participative informa-tion production, consideration of uncertainties, and broad com-munication) as the key factors leading towards higher levels of learning. Interestingly one case study in the Hungarian Tisza with a more rigid and centralized national regime showed signs of double

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[2] http://ec.europa.eu/environment/water/water-framework/pdf/wfd_newsletter_1.pdf.

and triple-loop learning which most likely can be attributed to the presence of a shadow network (Sendzimir et al., 2007). Management regimes characterized by a high level of top-down governance (i.e. Usbek AmuDarya, Ukranian Tisza, Portiguese Guadiana) were typically dominated by lower levels of learning. Regimes characterized by higher levels of learning (Australian Murray Darling, Dutch Rhine, German Elbe, to some extent South African Orange) seem to be characterized by a balance between top-down government dominated processes and bottom-up governance processes with strong stakeholder participation. Further comparative analyses based on more elaborate and detailed empirical data are currently undertaken.

These initial results support the hypotheses stated that more complex and diverse governance regimes have a higher adaptive capacity. However, it is still an open question how to overcome the state of single-loop learning that seems to characterize many attempts to adapt to climate change.

6. Discussion and conclusions

In this paper a conceptual framework has been developed to analyse change in resource governance regimes. The framework has both an analytical and a normative component. The analytical approach captures key attributes of governance regimes and suggests a more systematic approach to analysing structural characteristics of governance regimes and their influence on adaptive capacity and processes of social and societal learning. The influence of formal and informal institutions, the role of state and non-state actors, the nature of multi-level interactions and the relative importance of bureaucratic hierarchies, markets and networks are identified as major structural characteristics of governance regimes. Change is conceptualized as social and societal learning that proceeds in a stepwise fashion moving from single to double to triple-loop learning. Informal networks are considered to play a crucial role in such learning processes. The theory of complex adaptive systems (CAS) underpins these assumptions. The desirable property of CAS to adapt to new circumstances makes them at the same time difficult to predict and to control.

The normative component associates certain characteristics of governance regimes with higher resilience and adaptive capacity and thus also higher sustainability. The direction of institutional change is assumed to be directed at more flexible regulations that leave room for context specific implementation. A balance between formal and informal institutions that complement each other is seen as desirable. New approaches to manage uncertainty (e.g. participatory scenario development) and risk (e.g. risk dialogues, robust action) are implemented with corresponding efforts to change structural constraints. A major role is attributed to non-state actors. Important new roles/functions are boundary spanners, knowledge brokers and emergent leadership. Polycentric systems are assumed to have a higher adaptive capacity and to be less vulnerable to disturbance. More polycentric structures and balance between bottom-up and top-down approaches lead to higher adaptive capacity and thus also sustainability of a resource governance regime. Such systems are also characterized by more diverse governance structures without strong dominance of either bureaucratic hierarchies or markets or networks. Top-down, bottom-up, network and side-by-side governance elements exist in parallel. The characteristics outlined delineate a large class of possible systems that could be realized. This is no arbitrariness or lack of precision but rather a recognition that any specific governance regime emerges under certain historical, political, cultural, economic and environmental conditions. As pointed out in the introduction already, addressing the issues raised requires a framework of intermediate complexity.

This implies that it is sufficiently detailed to support context sensitive analysis without being case specific and thus not transferable.

There is a clear need to develop more inter-disciplinary and systemic approaches in the social sciences. Only by further developing and applying shared conceptual frameworks taking into account the real complexity of governance regimes we can build the knowledge base needed to advance our understanding to a state that we can give meaningful policy advice. Phrased in terms of a diagnostic approach this implies that we can provide flexible tools for a diagnosis of a resource governance problem and develop jointly with the problem owners strategies for dealing with it.

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References

Ammon, G., Fischer, M., Hickmann, T., Stemmermann, K. (Eds.), 1996. Föderalismus und Zentralismus: Europas Zukunft zwischen dem deutschen und dem französischen Modell. Schriftenreihe des Europäischen Zentrums für Föderalismus-Forschung Tübingen, vol. 11. Nomos Publishers, Baden-Baden, Germany.

Argyris, C., Schön, D., 1978. Organizational Learning: A Theory of Action Perspective. Addison Wesley, Reading, MA.

Armitage, D., 2008. Governance and the Commons in a multi-level world. International Journal of the Commons 2, 7–32.

Armitage, D., Marschke, M., Plummer, R., 2008. Adaptive co-management and the paradox of learning. Global Environmental Change 18, 86–98.

Arthur, W.B., 1994. Increasing Returns and Path Dependence in the Economy. University of Michigan Press, Ann Arbor.

Bates, B.C., Kundzewicz, Z.W., Wu, S., Palutikof, J.P. (Eds.), 2008. Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change. IPCC Secretariat, Geneva, p. 210.

Benz, A., 2004. Einleitung: Governance—Modebegriff oder nützliches sozialwissenschaftliches Konzept? In: Benz, A. (Ed.), Governance—Regieren in komplexen Regelsystemen: Eine Einführung. VS Verlag für Sozialwissenschaften, Wiesbaden, Germany, pp. 11–28.

Berkes, F., Folke, C., 2002. Back to the future: ecosystem dynamics and local knowledge. In: Gunderson, L.H., Holling, C.S. (Eds.), Panarchy: Understanding Transformations in Human and Natural Systems. Island Press, Washington, pp. 121–146.

Berkes, F., Colding, J., Folke, C., 2003. Navigating Social-Ecological Systems: Building Resilience for Complexity and Change. Cambridge University Press, UK.

Borowski, I., Le Bourhis, J., Pahl-Wostl, C., Barraqué, B., 2008. Spatial misfit in participatory river basin management: effects on social learning. a comparative analysis of German and French case studies. Ecology and Society 13 (1), 7 http://www.ecologyandsociety.org/vol13/iss1/art7/ (online).

Dedeurwaerdere, T., 2005. The contribution of network Governance to Sustainable Development. Les séminaires de l'IDDRI, no. 13, 2005, 15 pp.

Dietz, T., Ostrom, E., Stern, P., 2003. The struggle to govern the commons. Science 302, 1907–1912.

Duit, A., Galaz, V., 2008. Governance and complexity—emerging issues for governance theory. Governance An International Journal of Policy, Administration, and Institutions 21 (3), 311–335.

Evans, J., 1990. Bias in Human Reasoning: Causes and Consequences. Psychology Press, UK.

Finger, M., Allouche, J., 2001. Water Privatisation: Transnational Corporations and the Re-regulation of the Global Water Industry. Taylor & Francis, UK.

Flood, R., Romm, N., 1996. Diversity Management: Triple Loop Learning. Wiley, Chichester.

Folke, C., Hahn, T., Olsson, P., Norberg, J., 2005. Adaptive Governance of Social-Ecological Systems. Annual Review of Environment and Resources 30, 8.1–8.33.

Galaz, V.R., 2005. Does the EC Water Framework Directive build Resilience? Harnessing Socio-Ecological Complexity in European Water Management. Policy Paper I by "The Resilience and Freshwater Initiative". Swedish Water House, Stockholm.

Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Research Policy 31, 1257–1274.

Giddens, A., 1984. The Constitution of Society: Outline of the Theory of Structuration. University of California Press.

Gleick, P., 2003. Global freshwater resources: soft-path solutions for the 21st Century. Science 302, 1524–1528.

Gunderson, L., 1999. Resilience, flexibility and adaptive management—antidotes for spurious certitude? Conservation Ecology 3 (1), 7 http://www.consecol.org/vol3/iss1/art7 (online).

Hargrove, R., 2002. Masterful Coaching. Revised Edition. Jossey-Bass/Pfeiffer, Wiley, USA.

Harrison, N.E. (Ed.), 2006. Complexity in World Politics: Concepts and Methods of a New Paradigm. State University of New York Press, New York, USA, p. 214.

Heinelt, H., 2002. Achieving sustainable and innovative policies through participatory governance in a multi-level context: theoretical issues. In: Heinelt, H., Getimis, P., Kafkalas, G., Smith, R., Swyngedouw, E. (Eds.), Participatory Governance in Multi-level Context. Concepts and Experience. Leske + Budrich, Opladen, pp. 17–32.

Héritier, A., 2002. New modes of governance in Europe: policy-making without legislating? In: Héritier, A. (Ed.), Common Goods: Reinventing European and International Governance. Lanham, Md., Rowman & Littlefield Publishers, pp. 185–206.

Helmke, G., Levitsky, S., 2004. Informal institutions and comparative politics: a research agenda. Perspectives on Politics 2, 725–740.

Holling, C.S., Meffe, G.K., 1996. Command and control and the pathology of natural resource management. Conservation Biology 10, 328–337.

Holton, R.J., 1998. Globalization and the Nation-State. Palgrave, Basingstoke, UK.

Hooghe, L., Marks, G., 2003. Unraveling the central state but how? Types of multi-level governance. American Political Science Review 97, 233–243.

Huntjens, P., Pahl-Wostl, C., Grin, J., in press. The role of adaptive and integrated water management in coping with the impacts of climate change on floods and droughts in River Basins—a comparative analysis of four European sub basins. Regional Environmental Change.

Huntjens, P., Pahl-Wostl, C., Rihoux, B., Flachner, Z., Neto, S., Koskova, R., Schlueter, M., Nabide Kiti, I., Dickens, C., 2008. The role of adaptive and integrated water management (AIWM) in developing climate change adaptation strategies for dealing with floods and droughts—a formal comparative analysis of eight water management regimes in Europe, Asia, and Africa. Deliverable 1.7.9b of the NeWater project, Institute of Environmental Systems Research, University of Osnabruck, Germany.

Huntjens, P., Pahl-Wostl, C., Rihoux, B., Schlueter, M., Flachner, Z., Neto, S., Koskova, R., Dickens, C., Nabide Kiti, I., in review. Adaptive Water Management in a Changing Climate: A formal comparative analysis of eight water management regimes in Europe, Africa, and Asia.

Ingram, H., 2008. Beyond universal remedies for good water governance: a political and contextual approach. Paper presented at the Sixth Biennial Rosenberg Water Policy Forum on "Water For Food: Quantity and Quality in a Changing World", Zaragoza, Spain. URL: http://rosenberg.ucanr.org/documents/V Ingram.pdf.

Isendahl, N., Pahl-Wostl, C., Dewulf, A., 2008. Options for improving dealing with uncertainties in water management practice. NeWater Deliverable 1.7.3c.

Kingdon, J.W., 1992. Agendas Alternatives and Public Policies. HarperCollins, New York.

Kohler-Koch, B., 1999. The evolution and transformation of European Governance. In: Kohler-Koch, B., Eising, R. (Eds.), The Transformation of Governance in the European Union. Routledge, London, UK, pp. 14–35.

Kooiman, J., 2000. Societal governance: levels, models and orders of social–political interaction. In: Pierre, J. (Ed.), Debating Governance: Authority, Steering, and Democracy. Oxford University Press, Oxford, UK, pp. 138–164.

Kooiman, J., 2003. Governing as Governance. Sage, London, UK.

Levin, S.A., 1999. Fragile Dominion—Complexity and the Commons. Perseus Publishers, Cambridge, UK.

Lindner, J., 2003. Institutional stability and change: two sides of the same coin. Journal of European Public Policy 10, 912–935.

Ludwig, D., Walker, B., Holling, C.S., 1997. Sustainability, stability, and resilience. Conservation Ecology 1 (1), 7 http://www.consecol.org/vol1/iss1/art7/ (online).

Ludwig, D., 2001. The era of management is over. Ecosystems 4, 758–764.

Mayntz, R., 2006. Governance Theory als fortentwickelte Steuerungstheorie? In: Schuppert, G.F. (Ed.), Governance-Forschung: Vergewisserung über Stand und Entwicklungslinien. Nomos Verlag, Baden-Baden, Germany, pp. 11–20.

Mayntz, R., Scharpf, F.W., 1995. Der Ansatz des akteurszentrierten Institutionalismus. In: Mayntz, R., Scharpf, F.W. (Eds.), Gesellschaftliche Selbstregelung und politische Steuerung. Campus-Verlag, Frankfurt a.M, Germany, pp. 39–72.

McGinnis, M. (Ed.), 1999a. Polycentric Governance and Development: Readings from the Workshop in Political Theory and Policy Analysis. University of Michigan Press, Ann Arbor.

McGinnis, M. (Ed.), 1999b. Polycentricity and Local Public Economies: Readings from the Workshop in Political Theory and Policy Analysis. University of Michigan Press, Ann Arbor.

McGinnis, M. (Ed.), 2000. Polycentric Games and Institutions: Readings from the Workshop in Political Theory and Policy Analysis. University of Michigan Press, Ann Arbor.

Miller, J.H., Page, S.E., 2007. Complex Adaptive Systems: An Introduction to Computational Models of Social Life. Princeton University Press, Princeton, USA, 284.

Moss, T., 2007. Solving Problems of 'Fit' at the Expense of Problems of 'Interplay'? The Spatial Reorganisation of Water Management following the EU Water Framework Directive. In: Mollinga, P.P., Dixit, A., Athukorala, K. (Eds.), Integrated Water Resources Management. Global Theory, Emerging Practice and Local Needs. Sage Publications, New Delhi/Thousand Oaks/London, pp. 64–108.

Mostert, E., Pahl-Wostl, C., Rees, Y., Searle, B., Tàbara, D., Tippet, J., 2007. Social learning in European river basin management; barriers and fostering mechanisms from 10 river basins. Ecology and Society 12 (1), 19 http://www.ecologyandsociety.org/vol12/iss1/art19/ (online).

Nacurama, R., 1987. The textbook process and policy implementation research. Policy Studies Review 1, 142–154.

Newig, J., Pahl-Wostl, C., Sigel, K., 2005. The role of public participation in managing uncertainty in the implementation of the water framework directive. European Environment 15, 333–343.

Nooteboom, S., 2006, November. Adaptive Networks—The Governance for Sustainable Development. Eburon Academic Publishers, Delft, The Netherlands.

North, D.C., 1990. Institutions, Institutional Change and Economic Performance. Cambridge University Press, Cambridge.

Olsson, P., Gunderson, L.H., Carpenter, S.R., Ryan, P., Lebel, L., Folke, C., Holling, C.S., 2006. Shooting the rapids: navigating transitions to adaptive governance of social-ecological systems. Ecology and Society 11 (1), 18 (online).

Ostrom, V., Tiebout, C.H., Warren, R., 1961. The organization of government in metropolitan areas: a theoretical inquiry. American Political Science Review 55, 831–842.

Ostrom, E., 1990. Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press, New York, USA, 270 pp.

Ostrom, V., 1997. The Meaning of Democracy and the Vulnerability of Democracies. University of Michigan Press, Ann Arbor.

Ostrom, E., 2001. Vulnerability and Polycentric Governance Systems. IHDP (International Human Dimensions Programme on Global Environmental Change) Newsletter UPDATE no. 3, 1, 3–4.

Ostrom, E., 2005. Understanding Institutional Diversity. Princeton University Press.

Ostrom, E., 2007. A diagnostic approach for going beyond Panaceas. Proceedings of the National Academy of Sciences of the United States of America 104, 15181–15187.

Ostrom, E., 2008. Developing a method for analyzing institutional change. In: Batie, S., Mercuro, N. (Eds.), Assessing the Evolution and Impact of Alternative Institutional Structures. Routledge Press, London (available at SSRN: http://ssrn.com/abstract=997837).

Pahl-Wostl, C., 1995. The Dynamic Nature of Ecosystems: Chaos and Order Entwined. Wiley, Chichester, 288 pp.

Pahl-Wostl, C., 2006. The importance of social learning in restoring the multi-functionality of rivers and floodplains. Ecology and Society 11 (1), 10 http://www.ecologyandsociety.org/vol11/iss1/art10/ (online).

Pahl-Wostl, C., 2007a. Transition towards adaptive management of water facing climate and global change. Water Resources Management 21 (1), 49–62.

Pahl-Wostl, C., 2007b. Requirements for adaptive water management. In: Pahl-Wostl, C., Kabat, P., Möltgen, J. (Eds.), Adaptive and Integrated Water Management. Coping with Complexity and Uncertainty. Springer Verlag, Heidelberg, Germany, pp. 1–22.

Pahl-Wostl, C., 2007c. The implications of complexity for integrated resources management. Environmental Modelling and Software 22, 561–569.

Pahl-Wostl, C., Isendahl, N., Möllenkamp, S., Brugnach, M., Jeffrey, P., Medema, W., Tessa de Vries, T., 2006. Paradigms in Water Management. NeWater Project Deliverable D 1.1.2. URL: www.newater.info.

Pahl-Wostl, C., Jeffrey, P., Isendahl, N. and Brugnach, M., in review. Paradigms in Water Management: Reconciling what we do with what we know.

Pahl-Wostl, C., Möltgen, J., Ebenhöh, E., Holtz, G., 2007a. The NeWater management and transition framework—state and development process. In: Pahl-Wostl, C., Kabat, P., Möltgen, J. (Eds.), Adaptive and Integrated Water Management. Coping with Complexity and Uncertainty. Springer Verlag, Heidelberg, Germany, pp. 75–96.

Pahl-Wostl, C., Craps, M., Dewulf, A., Mostert, E., Tabara, D., Taillieu, T., 2007b. Social learning and water resources management. Ecology and Society 12 (2), 5 http://www.ecologyandsociety.org/vol12/iss2/art5/ (online).

Pahl-Wostl, C., Sendzimir, J., Jeffrey, P., Aerts, J., Berkamp, G., Cross, K., 2007c. Managing change toward adaptive water management through social learning. Ecology and Society 12 (2), 30 http://www.ecologyandsociety.org/vol12/iss2/art30/ (online).

Rhodes, R.A.W., 1997. Understanding Governance: Policy Networks, Reflexivity and Accountability. Open University Press, Buckingham.

Rhodes, R.A.W., 2000. Governance and Public Administration. In: Pierre, J. (Ed.), Debating Governance: Authority, Steering, and Democracy. Oxford University Press, Oxford, UK, pp. 54–90.

Rosenau, J.N., 1995. Governance in the 21st Century. Global Governance 1, 13–43.

Sabatier, P.A., 1999. The need for better theories. In: Sabatier, P.A. (Ed.), Theories of the Policy Process. Westview, Boulder, USA, pp. 3–17.

Scharpf, F.W., 1997. Games Real Actors Play: Actor-Centered Institutionalism in Policy Research. Westview Press, Oxford.

Schuppert, G.F., 2006. Governance im Spiegel der Wissenschaftsdisziplinen. In: Schuppert, G.F. (Ed.), Governance Forschung: Vergewisserung über Stand und Entwicklungslinien. Nomos Verlag, Baden-Baden, Germany, pp. 371–469.

Scott, R.W., 2001. Institutions and Organizations, 2nd ed. Sage Publications, Thousand Oaks.

Sendzimir, J., Magnuszewski, P., Flachner, Z., Balogh, P., Molnar, G., Sarvari, A., Nagy, Z., 2007. Assessing the resilience of a river management regime: informal

learning in a shadow network in the Tisza River Basin. Ecology and Society 13 (1), 11 http://www.ecologyandsociety.org/vol13/iss1/art11/ (online).

Smith, A., Stirling, A., Berkhout, F., 2005. The governance of sustainable socio-technical transitions. Research Policy 34, 1491–1510.

Thompson, G., Frances, J., Levacic, R., Mitchell, J. (Eds.), 1991. Markets, Hierarchies and Networks: The Co-ordination of Social Life. Sage Publishers, London, UK.

Tilman, D., 1999. The ecological consequences of changes in biodiversity: a search for general principles. Ecology 80 (5), 1455–1474.

Timmerman, J., Langaas, S., 2005. Water information: what it is good for? The use of information in transboundary water management. Regional Environmental Change 5, 177–187.

Tippet, J., Searle, B., Pahl-Wostl, C., Rees, Y., 2005. Social learning in public participation in River Basin Management. Environmental Science & Policy 8 (3), 287–299.

Treib, O., Bähr, H., Falkner, G., 2005. Modes of Governance: A Note Towards Conceptual Clarification. European Governance Papers (EUROGOV). No N-05-02. URL: http://www.connex-network.org/eurogov/pdf/egp-newgov-N-05-02.pdf.

Welch, S., Kennedy-Pipe, C., 2004. Multi-level governance and international relations. In: Bache, I., Flinders, M. (Eds.), Multi-Level Governance. Oxford University Press, Oxford, UK, pp. 127–144.

Wenger, E., 1998. Communities of practice; learning, meaning, and identity. Cambridge University Press, Cambridge, UK.

Young, O., 2007. Designing Environmental Governance Systems: The Diagnostic Method. Keynote at IDGEC Synthesis Conference, Bali 2006. Summary published in IHDP Newsletter, 1.2007, pp. 9–11.

Young, O., 2008. Building regimes for socioecological systems: institutional diagnostics. In: Young, O., King, L., Schroeder, H. (Eds.), Institutions and Environmental Change. MIT Press, Cambridge, MA, USA, pp. 115–144.