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Adaptive Water Management and Policy Learning in a Changing Climate: a Formal Comparative Analysis of Eight Water Management Regimes in Europe, Africa and Asia

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ABSTRACT
This article provides an evidence-based and policy-relevant contribution to understanding the phenomenon of policy learning and its structural constraints in the field of river basin management, in particular related to coping with current and future climatic hazards such as floods and droughts. This has been done by a formal comparative analysis of eight water management regimes, by using multi-value qualitative comparative analysis, focusing on the relationship between regime characteristics (as explanatory variables) and different levels of policy learning (as output value). This research has revealed the importance of the socio-cognitive dimension, as an essential emerging property of complex adaptive governance systems. This socio-cognitive dimension depends on a specific set of structural conditions; in particular, better integrated cooperation structures in combination with advanced information management are the key factors leading towards higher levels of policy learning. Furthermore, this research highlights a number of significant positive correlations between different regime elements, thereby identifying a stabilizing mechanism in current management regimes, and this research also highlights the necessity of fine-tuning centralized control with bottom-up approaches. Copyright © 2011 John Wiley & Sons, Ltd and ERP Environment.

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Introduction

GOVERNMENT CAN NO LONGER IGNORE THE TURBULENCE AND COMPLEXITY OF ITS OPERATING ENVIRONMENT (Leicester, 2007). Instead, it needs to find its own treasure within.[1] This is the case for policy learning (Sabatier, 1988; Sabatier & Jenkins-Smith, 1993; Leicester, 2007). In his book *System Failure* Chapman (2002) made a strong argument for learning within government as the key way to handle complexity and its associated lack of predictability and control. According to Leicester (2007) a key part of the challenge is to encourage government itself to participate in the learning process, and to overcome the psychological and structural constraints it faces that militate against learning.

Policy learning approaches generally hold that states can learn from their experiences and that they can modify their present actions on the basis of their interpretation of how previous actions have fared in the past (Sabatier, 1988; Bennett and Howlett, 1992). However, many of the fundamental elements of such learning remain conceptually unclear and, as a result, the entire phenomenon of experience-induced policy change remains difficult to operationalize (Bennett and Howlett, 1992; Sabatier & Jenkins-Smith, 1993; Chapman, 2002; Sanderson, 2002; Kemp & Weehuizen, 2005; Grin & Loeber, 2007; Leicester, 2007). This paper intends to build an evidence-based contribution to understanding the phenomenon of policy learning and its structural constraints in the field of river basin management, in particular related to coping with the most common extreme events: floods and droughts.

The challenges posed by climate-related extreme events to river basins are manifold, especially as water resource issues interact with a wide range of environmental and socio-economic sectors including health, public safety, agriculture, biodiversity, industry, navigation and tourism. There are multiple lines of evidence that climate change is happening now, and the impacts are being seen now (IPCC, 2007; IARU, 2009; Human Impact Report, 2009; World Water Development Report, 2009), and in many places climate-related events have become more frequent and more extreme (World Water Development Report, 2009). Many key climate indicators are already moving beyond the patterns of natural variability within which contemporary society and economy have developed and thrived. These indicators include global mean surface temperature, sea-level rise, global ocean temperature, Arctic sea-ice extent, ocean acidification and extreme climatic events (IARU, 2009). Recent observations show that greenhouse gas emissions and many aspects of the climate are changing near the upper boundary of the Intergovernmental Panel on Climate Change (IPCC) range of projections (IARU, 2009). In other words, climate change is happening more rapidly than anyone thought possible (Human Impact Report, 2009; IARU, 2009). Hence, it is increasingly recognized that we need to adapt to the challenges and opportunities that a changing climate will bring. Doing nothing is not an option, especially if one realizes that for every euro invested in disaster preparedness, six euros could be saved in reconstruction costs after disasters have been taken place (UNEP, 2004). In other words, climate change adaptation is vital and unavoidable.

Given the expected increase of climate-related extreme events, water management capabilities in case studies, and on a global scale, will be tested to their limits by the effects of climate change. This requires innovative and adaptive ways of managing water, which can be referred to as 'adaptive and integrated water management' (AIWM). This paper addresses the role of AIWM in developing climate change adaptation strategies to deal with impacts of climate change on floods and droughts. For this purpose we will conduct a formal comparative analysis of the water management regimes and related adaptation strategies in selected case studies.

The case studies in this paper represent the whole spectrum of traditional water management (command and control regimes) and adaptive and integrated water management regimes (management as learning approach).[2] Additionally, all case studies are being confronted with an increasing intensity and frequency of flood and/or

[1]The Delors Commission for UNESCO on education for the 21st century called learning 'the treasure within'.
[2]Based on a baseline assessment of all case-studies in the EU NeWater-project (www.newater.info).

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droughts (Huntjens, *et al.* 2008), as being the most common extreme events (World Water Development Report, 2009). The case studies in this paper include eight river basins in Africa, Asia and Europe: (1) Rivierenland in the Netherlands, as a sub-basin of the Rhine; (2) Alentejo region in Portugal, as a sub-basin of the Guadiana; (3) Hungarian part of the Upper Tisza; (4) Ukrainian part of the Upper Tisza (also called the Zacarpathian Tisza); (5) Ohre Basin in Czech Republic, as a sub-basin of the Elbe; (6) Kagera Basin in Uganda, Rwanda, Burundi and Tanzania, as a sub-basin of the Nile; (7) Lower AmuDarya in Uzbekistan, as a sub-basin of the AmuDarya; (8) and Upper Vaal catchment in South Africa, as a sub-basin of the Orange.

This paper focuses on conditions and processes at the sub-basin level (e.g. water boards) but these are embedded in a wider context (e.g. institutional setting at different levels). The sub-basin level is conceived as the level at which all elements of a water management regime are at play. At the same time this level is influencing, or is being influenced by, higher and lower levels of management. This central position also allows us to assess the outcomes of a water management regime at the operational level, as the management on the sub-basin level (e.g. water board or regional water authority) is influenced by international or national regulation, while implementing at the operational/local level.

The characteristics (see next section) of AIWM are regarded here as working hypotheses, as the change towards more adaptive management regimes is as yet slow and empirical data and practical experience are thus limited, in particular regarding the interdependence of elements of the management regime. The strong interdependence of the factors stabilizing current management regimes is also one possible reason for this lack of innovation. One cannot, for example, move easily from top-down to participatory management practices without changing the whole approach to information and risk management. Hence, research is urgently needed to better understand the interdependence of key elements of water management regimes and the dynamics of transition processes in order to be able to compare and evaluate alternative management regimes and to implement and support transition processes if required (Pahl-Wostl *et al.*, 2007a).

The key research question in this article is whether a higher level of AIWM reveals a different response in coping with floods and droughts than management regimes with a lower level of AIWM. This will be done by looking at different levels of policy learning (Hall, 1988; Bennett and Howlett, 1992; Argyris, 1999; Hargrove, 2002; Sanderson, 2002), being reflected and/or consolidated in the adaptation strategies to deal with either floods and/or droughts. We define policy learning as a 'deliberate attempt to adjust the goals or techniques of policy in the light of the consequences of past policy and new information so as to better attain the ultimate objects of governance' (Hall, 1988: 6).

It is important to acknowledge that the adaptation strategies being studied may not have achieved their projected outcomes yet, as there normally is a time lag between policy development and actual implementation. Nevertheless, for a governance regime to deal with the current and anticipated impacts of climate change it first needs to have a policy or strategy in place, either for flood protection or for drought resilience, or both. From this perspective, the output of a governance system is not only defined by its physical interventions but also by means of its management interventions. The case studies are selected because they all are confronted with climatic hazards and all have strategies in place, being defined as outputs of extensive policy processes.

Adaptive and Integrated Water Management

Despite the fact that the concept of IWRM[3] is widely accepted as the appropriate framework to deal with complex water resources management issues, the scientific base for IWRM is not yet fully developed. It lacks both empirical knowledge and concepts that allow effective transfer of successful experiences across basins and frontiers. More flexible approaches, such as adaptive water management, have been advocated as an essential and timely extension of the IWRM approach to improve the conceptual and methodological base to realize the goals of IWRM (Moberg and Galaz, 2005; Pahl-Wostl and Sendzimir, 2005; Pahl-Wostl, 2007b).

[3]One of the most often referred to definitions of IWRM is the one by the Global Water Partnership (GWP) defining IWRM as 'a process which promotes the co-ordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.' (GWP-TEC, 2000).

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To deal with existing and new complexities, water resources management must be able to respond to changes in the natural and social environment and to anticipate associated uncertainties (Folke *et al.*, 2005; Pahl-Wostl *et al.*, 2007b). Adaptation to climate change and management of related risks should therefore be built into water resources management plans and programmes. Adaptive and integrated management is considered to be an appropriate approach for doing so. Adaptive and integrated management can be defined as a structured process for improving systemic management policies and practices by learning from the outcomes of implemented management strategies (Pahl-Wostl *et al.*, 2007b). By re-evaluating goals, objectives and means by which to achieve them as new information and insight become available, adaptive management is more responsive to changing conditions of, and demands on, ecosystems as compared with traditional approaches to water resource management.

AIWM requires different capabilities from traditional forms of water management, particularly when it comes to creating forms of collaboration between water managers and stakeholders, the relationship between science and policy, the importance of participatory learning processes, dealing with uncertainty, and assessing a wide variety of possible measures and future scenarios. It requires many instances of social learning to implement and sustain innovative management approaches (Pahl-Wostl *et al.*, 2007b). As Folke *et al.* (2005) have pointed out, social learning is needed to build experience for coping with uncertainty and change. They emphasize that 'knowledge generation in itself is not sufficient for building adaptive capacity in social-ecological systems to meet the challenge of navigating nature's dynamics' and conclude that 'learning how to sustain social-ecological systems in a world of continuous change needs an institutional and social context within which to develop and act'. Knowledge and the ability to act upon new insights are continuously enacted in social processes. Hence, the social network of stakeholders is an invaluable asset for dealing with change (Chapman, 2002; Pahl-Wostl and Hare, 2004; Folke *et al.*, 2005). In short, adaptive management requires a process of active learning by all stakeholders, and continuous improvement of management strategies by learning from the outcomes of implemented policies (Geldof, 1995; Pahl-Wostl, 2007b).

In technology-dominated water management practice, design and structure of governance regimes has not played a prominent role. AIWM implies a real paradigm shift in water management from what can be described as a prediction and control to a management-as-learning approach. Such change aims to increase the adaptive capacity of river basins at different scales and implies a change in the whole water management regime (Pahl-Wostl, 2007b). Some structural requirements for a water management regime to be adaptive are summarized in Table 1. Two different regimes characterized by two different management paradigms – management as control versus management as learning – are contrasted as the extreme, opposing ends of six axes.

Interdependence of the Regime Characteristics and Policy Learning

The key objective of our research is to see whether there is a link between regime characteristics and policy learning (as an output of the regime at play). For this purpose we needed to develop two different and independent analytical frameworks:

(1) A framework for assessing the characteristics of a water management regime
(2) A framework for assessing different types or levels of policy learning.

Below we provide the conceptual background for both frameworks and related development of indicators.

A Framework for Assessing the Characteristics of a Water Management Regime

We developed a normative framework of how an adaptive and integrated management regime looks like, in order to develop indicators for assessing the regime characteristics. For this normative framework we have used the working hypotheses on the characteristics of AIWM presented in Table 1. These working hypotheses have been further developed into a methodology for evaluating the level of AIWM (Huntjens *et al.*, 2010; Raadgever *et al.*, 2008). Additional variables were included based on relevant literature (Huntjens *et al.*, 2010). This resulted in an analytical framework for assessing regime characteristics, consisting of 64 indicators divided over nine dimensions of

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Dimension	Prediction, Control Regime	Integrated, Adaptive Regime
Governance	Centralized, hierarchical, narrow stakeholder participation	Polycentric, horizontal, broad stakeholder participation
Sectoral Integration	Sectors separately analysed resulting in policy conflicts and emergent chronic problems	Cross-sectoral analysis identifies emergent problems and integrates policy implementation
Scale of Analysis and Operation	Transboundary problems emerge when river sub-basins are the exclusive scale of analysis and management	Transboundary issues addressed by multiple scales of analysis management
Information Management	Understanding fragmented by gaps and lack of integration of information sources that are proprietary	Comprehensive understanding achieved by open, shared information sources that fill gaps and facilitate integration
Infrastructure	Massive, centralized infrastructure, single sources of design, power delivery	Appropriate scale, decentralized, diverse sources of design, power delivery
Finances and Risk	Financial resources concentrated in structural protection (sunk costs)	Financial resources diversified using a broad set of private and public financial instruments

Table 1. Different regimes and their characteristics (from Pahl-Wostl *et al.*, 2007b)

AIWM: (1) agency; (2) awareness raising and education; (3) type of governance; (4) cooperation structures; (5) policy development and implementation; (6) information management and sharing; (7) finances and cost recovery; (8) risk management; (9) and effectiveness of (international) regulation.

A Framework for Assessing Different Types of Policy Learning

A second and independent methodology has been developed (see Huntjens *et al.*, 2008) for assessing the levels of policy learning being observed in the adaptation strategies of each water management regime. The adaptation strategies for dealing with floods and/or droughts are defined as an output of a water management regime.

Policy learning is a concept that has been used by different authors in the field of public administration (e.g. Hall, 1988; Sabatier, 1988, Bennett and Howlett, 1992; Sabatier & Jenkins-Smith, 1993; Sanderson, 2002; Grin & Loeber, 2007; Leicester, 2007). Policy learning involves a socially conditioned discursive or argumentative process of development of cognitive schemes or frames which questions the goals and assumptions of policies (Sanderson, 2002: 6).

Policy changes have been explained in terms of learning by Sabatier (1988) and Sabatier and Jenkins-Smith (1993, 1999) through their advocacy coalition framework (ACF). However, one limitation in the ACF is that advocacy coalitions take their identity from core beliefs, they are conservative of them and thus also of the policy positions they advocate (Weible *et al.*, 2009). Conservatism led Sabatier and Jenkins-Smith (1993) to propose that collective learning appears not from change within policy coalitions but as a result of the changing influence of policy coalitions on the whole. In this model, the system learns without any learning on the part of policy coalitions or individuals. Movement is argued to be stimulated by shocks and trends exogenous to the system – including wider political change, legislative reform or stressors such as climate change. By doing so, the ACF does not explicitly account for, or is ambiguous about, the role of ideas and self-interest in the policy process (e.g. Kübler, 1999; Compston and Madsen, 2001). In recent years there has been some reconsideration (see also Weible *et al.*, 2009) but still processes of reinterpretation and reframing are not very prevalent. Furthermore it exclusively focuses on actors.

It is important to recognize that policies change in a variety of different ways. As has long been recognized, some policies are new and innovative, while others are merely incremental refinements of earlier policies (Hogwood and Peters, 1983; Polsby, 1984). In other words, policy learning may have different levels of intensity (Pahl-Wostl *et al.*, 2007b). For distinguishing between different levels of policy learning we use the concept of double loop learning (Argyris, 1999) and triple loop learning (Hargrove, 2002), as an extension of the double loop concept (see Figure 1). From an analytical perspective the double and triple loop learning concepts are better suited for our comparative analyses than other policy learning concepts, as they enable us to address the various levels of learning, for example

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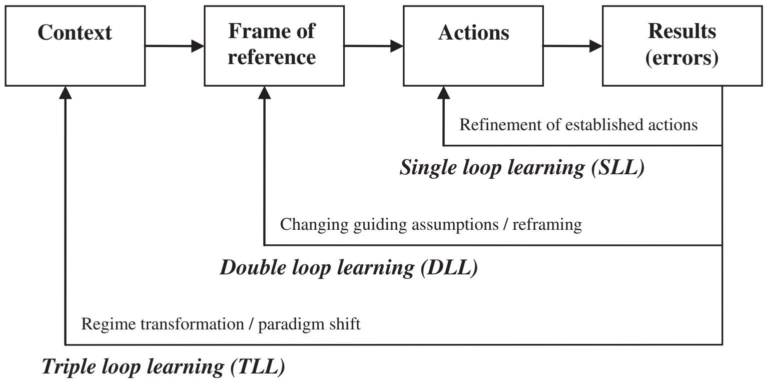

Figure 1. Triple loop learning concept derived from Hargrove (2002)

in contrast to the ACF of Sabatier and Jenkins-Smith (1988, 1993, 1999). This is also important for conducting a multi-value qualitative comparative analysis (mvQCA), as Boolean minimization requires dichomotization of an output value (see section on mvQCA).

To distinguish different learning processes and how to classify them according to the triple loop concept it is useful to start with some definitions (based on Hargrove, 2002):

- **Single loop learning (SLL)** – refinement of established actions to improve performance without changing guiding assumptions or without taking entirely alternative actions into account (e.g. increase height of dykes to improve flood protection).
- **Double loop learning (DLL)** – change in the frame of reference and guiding assumptions (e.g. increase boundaries for flood management and encourage collaboration across national boundaries in large river basins).
- **Triple loop learning (TLL)** – transformation of context to change factors that determine the frame of reference. This kind of learning refers to transitions of the whole regime. Values and norms are shaped and stabilized by the structural context.

The triple loop concept of Hargrove (2002) has been operationalized into a list of indicators (Table 2) for assessing the type of learning being reflected in the most advanced adaptation strategies in the case studies under consideration (see Table 5). The purpose of this assessment is to determine which type of learning is dominant in each of these strategies. To be able to conduct an mvQCA it is necessary to have a binary outcome. Hence, based on the assessment presented in Table 5 below we have made a distinction between case studies dominated by single loop learning/ad-hoc problem solving and case studies dominated by double loop learning (including elements of triple loop learning). In other words, for this specific mvQCA it is not strictly required to make an operational distinction between double loop learning and triple loop learning, although we will still use the conceptual distinction for fine-tuning our analysis.

Data Collection and Research Methods

Not much work is available on comparative analyses of river basins that include the full range of a water management regime's complexity (Wolf, 1997; Myint, 2005). This research is one of the first of its kind in comparing complex water management regimes in a semi-quantitative way, but also by making operational the concepts of AIWM and policy learning. Additionally, the method (mvQCA) for analysing the relationship between regime characteristics and policy learning has not been applied before in this specific field nor in this specific way.

A calibrated approach, using a standardized questionnaire for the characteristics of a water management regime, and a questionnaire for determining key characteristics of adaptation strategies (see Table 5), expert judgement for both questionnaires and reinterpretation of outcomes by means of relevant literature was used to compare the water management regimes in the selected case studies. A complete outlay of the questionnaires being used for data collection can be found in Huntjens *et al.* (2007).

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Type of learning	Indicators
Single loop learning (SLL)	(1) When small changes are made to specific practices or behaviours, based on what has or has not worked in the past. This involves doing things better without necessarily examining or challenging underlying beliefs and assumptions (Kahane, 2004). In other words, goals, values, plans and rules are operationalized rather than questioned (Argyris and Schön, 1974) (2) When goals, values, frameworks and, to a significant extent, strategies are taken for granted. The emphasis is on 'techniques and making techniques more efficient' (Usher and Bryant: 1989: 87); for example, increase height of dykes for flood protection
Double loop learning (DLL)	(1) When modifications (as the result of learning) are occurring, or have occurred, in personnel, programmes, and legal and organizational structures that **incorporate new information** (including policy feedback) and causal understandings that yield more intellectually perceptive processes, a wider range of capabilities, and more effective policy (Brown, 2000:3) (2) When actor networks are being changed by including **new and different stakeholders**, supporting reflection on own assumptions and showing new possibilities. The social network of stakeholders is being used as an invaluable asset for learning and dealing with change (Folke *et al.*, 2005; Geels *et al.*, 2004) (3) When **uncertainties** are being identified, as a first step that is needed to find solutions (Brugnach *et al.*, 2008), and when (identified) uncertainties have been taken into account in current policy-making, for example by adaptation strategies based on climate change scenarios (Huntjens *et al.*, 2007)
Triple loop learning (TLL)	(1) When horizons of possibility are being expanded (Hargrove, 2002: 118), for example by developing and implementing entirely **new management measures** or entirely **new physical interventions** in the river basin (Huntjens *et al.*, 2007) (2) When a **paradigm shift** takes place that alters our way of thinking and behaviour (Hargrove, 2002: 119; Pahl-Wostl *et al.*, 2006) (3) When a major structural change has been taking place in the **regulatory framework** for dealing with floods or droughts

Table 2. Overview of indicators for assessing the type of learning reflected in the most advanced adaptation strategies in the case studies under consideration. For each indicator, reference to related literature is provided

In this research, expert judgment has been used as a method for knowledge elicitation on regime elements and internal processes. We are aware of the possibility of differential biases, given that some basins are located in more open societies than others, and what is 'truth' or which 'truth' should be communicated to whom can be quite different in different cultures. Hence, much care was devoted to assess the robustness of expert judgment. We have tried to reduce biased results by including the perspectives from civil society, (independent) researchers and other non-governmental parties, next to government officials. A prerequisite for reducing biased results is then to have an equal and fair representation of stakeholders involved. This is based on the basic 'constructivist' assumption that there is variety of different knowledge frames and mental models within one society as regards a complex policy problem such as climate change adaptation. For this research we have aimed to have an equal representation by selecting experts from three main categories: (1) academia, (2) government officials/policy-makers and (3) non-governmental stakeholders (e.g. civil society, water users and the private sector).

The list of potential respondents for each case study was developed in close cooperation with the NeWater case study teams embedded/located in the basin areas. The respondents list was compiled by selecting a group of respondents with enough knowledge on the case study under consideration, and the ability to answer the whole questionnaire, or at least a major part of it. Moreover, with the objective of including all relevant perspectives and experiences in the case study the respondents group was selected as a reflection of the most relevant stakeholders. This resulted in a consultation round involving a minimum of ten experts in each case study, reflecting perspectives from different categories (Table 3).

The reason for developing standardized answering options in the questionnaire is that it supports a formal comparative analysis of the results. Furthermore, the questionnaire allows us to assign weights to each indicator. In this way it is possible to aggregate multiple indicators, resulting in a score for one variable, or for aggregated variables, resulting in a score for one meta-variable (e.g. category of variables). Qualitative data were collected in

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Case-studies		Academia	Government	Non-Government	*Total no. of experts*
1	Lower Guadiana - Alentejo, Portugal	4	2	4	10
2	Ukrainian part of Upper Tisza	3	6	3	12
3	Hungarian part of Upper Tisza	3	4	3	10
4	Lower Rhine - Rivierenland, Netherlands	2	6	2	10
5	Upper Elbe - Ohre, Czech Republic	4	4	2	10
6	Lower AmuDarya - Uzbekiskan	5	4	4	13
7	Upper Nile - Kagera, Uga/Tan/Rwa/Bur	1	5	4	10
8	Upper Orange - Upper Vaal, S-Africa	2	2	2	6
	Total	24	32	24	**81**
	Percentage	30%	40%	30%	

Table 3. Overview of the number of experts (per category) consulted in each case study

such a way that it was possible to compare weighted averages on each separate indicator. The weighted average has been calculated by multiplying each individual score by the weight which respondents assigned to it; the total sum of all respondents in one case study was then divided by the total assigned weight (by adding up all weights assigned to this specific indicator). For the statistical analyses we have used the Pearson correlation coefficient (Pearson's *r*). It is obtained by dividing the covariance of the two variables by the product of their standard deviations. The Pearson correlation is +1 in the case of a perfect positive (increasing) linear relationship (correlation) and −1 in the case of a perfect decreasing (negative) linear relationship (anti-correlation). Generally, correlations above 0.80 are considered high, but for sifting out significant correlations in our analysis ($n = 8$) we have set the level of significance at $P > 0.9$ and $P < -0.9$. More details on data processing are given in Huntjens *et al.* (2007, 2008).

Comparative Assessment of the Management Systems

Table 4 provides an overview of all significant correlations between the variables in our framework for assessing a water management regime. For a complete overview of correlation coefficients see Huntjens *et al.* (2008).

Table 4 reveals many positive correlations between variables from different regime elements. This suggests a strong interdependence of the elements within a water management regime, and as such this interdependence is a

Variable	Is positively correlated with variable:
Joint/participative information production	Vertical cooperation ($P = 0.91$), transboundary cooperation ($P = 0.95$), consideration of uncertainties ($P = 0.95$) and broad communication ($P = 0.90$)
Levels of, and provisions for, stakeholder participation	Consideration of possible measures ($P = 0.96$) and risk perception ($P = 0.95$)
Vertical cooperation	Bottom-up governance ($P = 0.97$), joint/participative information production ($P = 0.91$) and consideration of uncertainties ($P = 0.90$)
Consideration of uncertainties	Time horizon in policy development (0.90), consideration of possible measures (0.90), broad communication ($P = 0.90$), utilization of information ($P = 0.94$), joint/participative information production ($P = 0.95$) and vertical cooperation ($P = 0.90$)
Monitoring and evaluation	Elicitation of mental models/critical self-reflection about assumptions ($P = 0.95$)
Risk perception	Consideration of possible measures ($P = 0.95$)
Vertical conflict resolution	Level of compliance to (inter)national regulation ($P = 0.91$)
Utilization of information	Time horizon in policy development ($P = 0.96$) and consideration of possible measures ($P = 0.91$)

Table 4. Overview of all significant correlations between the variables in our framework for assessing a water management regime

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stabilizing factor in current management regimes. For example, based on the positive correlations between joint/participative information production, vertical cooperation, transboundary cooperation, consideration of uncertainties and broad communication we can conclude that a lack of consensual knowledge is an important obstacle for cooperation, and vice versa, especially when dealing with uncertainty and change, which is also suggested by other researchers (Stubbs and Lemon, 2001; Tompkins and Adger, 2004; Olsson *et al.*, 2006). The observed correlations provide evidence that different regime elements are highly interconnected, especially indicators of the regime elements *cooperation structures* and *information management* (Table 5). After all, stakeholders who have been working together at one stage will probably meet each other in the next stage of policy making, taking with them their mutual (dis)trust, their history of (un)resolved conflicts, jointly produced information, existing collaboration forms or agreements, and norms or rules agreed upon previously. The concept of social learning has as its central hypothesis that the management of content and social involvement are strongly interdependent and cannot be separated (Pahl-Wostl *et al.*, 2007a). Content management relates to the processing of factual information on a problem, while social involvement refers to essential elements of social processes such as the framing of the problem, the management of the boundaries between different stakeholder groups, the type of ground rules and negotiation strategies chosen or the role of leadership in the process (Pahl-Wostl *et al.*, 2007a). An important hypothesis in the concept of social learning is that information management and social (cooperation) structures are interlinked, which corresponds to the socio-cognitive theory of information systems (Hemingway, 1998). Hemmingway focused on the impacts of the information presented on learning and action, and the centrality of the selection and organization of information to the nature of organizational forms. Our research confirms that information management and social (cooperation) structures are interlinked in the management systems under consideration. This interdependency can be described as the socio-cognitive dimension of water management regimes. We define the socio-cognitive dimension as the integrated cognitive and social properties of complex systems and related processes (e.g. social learning and participative processes). These (informal) learning environments are an emergent property of the interlinkage between information management and social cooperation structures, and are perceived to be crucial for the adaptive governance of socio-ecological systems (Folke *et al.*, 2005; Pahl-Wostl and Sendzimir, 2005).

The weighted averages on governance suggest that bottom-up governance does not play such a primary role in AIWM as earlier suggested. For example, the weighted average on governance in Rivierenland (Table 5) indicates that there is much more top-down governance than could be expected from consensus-based decision-making, particularly as the Netherlands is well known for its consensus-based decision-making (also called the 'Poldermodel'). All the case studies in this research seem to be in a process of finding a balance between bottom-up and top-down governance. A discussion revolving around the need to finely balance bottom-up approaches with centralized control is given by Huntjens *et al.* (2010).

In summary, for large-scale, complex multiple-use systems, such as river basins, this research suggests that bottom-up governance and decentralization is not a straightforward solution to water management problems. There will probably always be the need for a certain degree of top-down governance (or centralization), where a central authority has the responsibility and resources for issues such as facilitation of participatory processes, setting of standards, capacity building, conflict resolution and cooperation across boundaries. Additionally, a central authority is often needed to provide information and knowledge that is not available or accessible at the 'grass-roots' level.

Comparative Assessment of the Levels of Policy Learning

The next step in this study is an assessment of the outputs of the management regimes under consideration. The outputs are being defined as the levels of policy learning in river basin management (being reflected and/or consolidated by adaptation strategies to deal with either floods or droughts). This section presents the results from literature review and expert judgment on the indicators defined in Table 2. An overview of the results is presented in Table 6. A more detailed description of the key characteristics of each strategy is given in Huntjens *et al.* (2008).

It should be taken into account that the management regimes may be currently in the process of developing climate change adaptation strategies to deal with floods and/or droughts. In other words, even when a new management

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		Rivierenland (Lower Rhine)	Alentejo (Lower Guadiana)	Ohre Basin (Upper Elbe)	Ukraine (Upper Tsiza)	Hungary (Upper Tsiza)	Uzbekistan (Lower Amu Darya)	Kagera Basin (Upper Nile)	Upper Vaal (Upper Orange)
Type of governance	Top-down (=0) versus Consensual (bottom-up) governance (=2)	0.9	0.0	0.4	0.4	0.2	0.1	0.2	0.4
overall		**0.9**	**0.0**	**0.4**	**0.4**	**0.2**	**0.1**	**0.2**	**0.4**
Cooperation	Legal provisions concerning access to information, participation in decision-making (e.g. consultation requirements) and access to courts	2.0	1.5	1.7	1.3	1.4	0.7	1.2	2.0
	Co-operation structures include non-governmental stakeholders	1.5	0.7	1.0	0.9	0.7	0.3	0.8	1.5
	Non-governmental stakeholders actually contribute to agenda setting, analyzing problems, developing solutions and taking decisions ("co-production")	1.3	0.4	1.0	0.8	1.0	0.3	1.1	1.3
	Non-governmental stakeholders undertaken parts of river basin management themselves, e.g. though water users' associations	1.3	0.7	0.7	0.3	0.8	0.8	1.0	1.3
	Sectoral governments actively involve other government sectors	1.8	0.9	1.6	1.1	0.3	1.4	0.5	1.2
	Co-operation structures include government bodies from different sectors; many contacts generally	1.7	1.0	1.4	1.6	0.5	1.3	0.9	1.6
	Conflicts are dealt with constructively, results in inclusive agreements to which the parties are committed	1.4	1.3	1.0	1.3	0.2	1.1	1.0	1.0
	Lower level governments are involved in decision-making by higher level governments	2.0	0.4	1.4	1.3	0.5	0.6	1.1	1.0
	Co-operation structures include government bodies from different hierarchical levels; many contacts generally	1.9	1.0	1.2	1.2	1.0	0.6	1.1	1.4
	Conflicts are dealt with constructively, resulting in inclusive agreements to which the parties are committed	1.8	1.0	1.2	1.0	0.8	1.6	1.1	1.0
	Downstream governments are involved in decision-making by upstream governments	1.6	1.1	1.6	1.2	1.0	1.1	1.3	1.3
	International/transboundary co-operation structures exist (e.g. river basin commissions); many contacts generally	1.9	1.3	1.9	1.4	1.2	1.3	1.6	2.0
	Conflicts are dealt with constructively, resulting in inclusive agreements to which the parties are committed	1.6	1.3	1.2	1.2	0.8	1	1.3	1.3
overall		**1.7**	**1.0**	**1.3**	**1.1**	**0.8**	**0.9**	**1.1**	**1.4**

Information Management & Sharing	Different government bodies are involved in setting the TORs and supervising the search, or at least consulted (interviews, surveys etc.)	1.7	0.9	1.9	1.0	0.3	1	1.0	1.0
	Non-governmental stakeholders are involved in setting the TORs and supervising the search, or at least consulted (interviews, survey etc.)	1.6	0.5	1.3	0.7	0.6	0.4	0.6	1.2
	In addition to technical and engineering sciences also for instance ecology and the social sciences are involved in defining and executing the research	2.0	1.1	1.4	1.3	0.8	1.1	1.6	1.6
	Researchers allow their research to be challenged by stakeholders and present their own assumption in as far as they are aware of them	1.6	0.5	1.3	1.0	0.5	1	1.8	1.2
	Research results are presented in a facilitative way, to stimulate reflection by the stakeholders about what is possible and what it is they want	1.9	0.4	1.7	1.1	0.4	1	1.6	1.4
	Uncertainties are not glossed over but communicated (in final reports, orally)	1.3	0.4	1.4	0.6	0.2	0.4	0.8	1.2
	Researchers are willing to talk with stakeholders about uncertainties	2.0	1.0	1.4	1.2	0.5	0.1	0.9	1.4
	Government exchange information and data with other governments	1.9	1.1	1.7	1.3	1.0	1	0.9	1.6
	Governments actively disseminate information and data to the public: on the Internet, but also by producing leaflets, though the media, etc.	1.9	0.9	1.4	1.2	0.6	1.1	0.9	1.8
	New information is used in public debates (and is not distorted)	1.9	1.0	1.6	0.6	0.5	0.2	1.0	1.5
	New information influences policy (not specifically related to CC)	1.8	1.0	1.3	1.0	1.0	0.7	0.7	1.4
	River basin information systems are up to standards	2.0	0.8	1.7	0.8	0.9	0.4	0.1	1.8
overall		**1.8**	**0.8**	**1.5**	**1.0**	**0.6**	**0.7**	**1.0**	**1.4**

Table 5. Overview of the results (weighted averages) of expert judgement on each indicator in the regime elements *Type of Governance*, *Cooperation Structures* and *Information Management* (from Huntjens *et al.*, 2008). '0' indicates a condition belonging to a non-adaptive and non-integrated regime; and '2' as a condition belonging to an adaptive and integrated regime. This type of scoring is a prerequisite for our method (mvQCA; for more details see supporting appendix and Huntjens *et al.* 2008)

Variable	Rivierenland	Alentejo	Ohre	Tisza in Ukraine	Tisza in Hungary	AmuDarya	Kagera	Upper Vaal
Strategy's name	Room for Rivers	No strategy	Plan of Main Basins (Period 2007-2012) + Nat Progr. Reduction of CC impacts (2004)	Program of Integrated Anti-Flood Protection in Zacarpathian Tisza (2006)	National CC Strategy (2004) + new Vásárhelyi Plan (VTT, 2003)	No strategy	No strategy	National Climate Change Response Strategy (DEAT, 2004)
Current status in strategy development	Fully developed flood strategy (PKB RvdR 2006), based on CC scenarios	Problem identification (droughts) in Albufeira Convention	Ratified in 2007	Fully developed flood strategy for period 2007-2015	Strategic goal setting (approved by Governm.)	Problem identification (developed CC scenarios)	Problem identification only by academics	Translation of strategy into operational policy has not occurred yet
Strategy's objectives	1) Capacity of 16,000 m3/s in 2015 2) Environmental quality 3) Reservation of space for 18.000 m3/s in 2050	N.A. at this stage	1) Flood protection 2) Increase storage cap. of reservoirs 3) Nature conservation	Flood protection for period 2007-2015, but not based on CC scenarios	Nat. CCS is a guideline for mitigation and adaptation for different sectors (2008-2025); VTT > flood protection, rural development, nature conservation	N.A. at this stage	N.A. at this stage	Offset vulnerability to climate change, amongst others by WRM and contingency planning
Allocated budget	2.1 Billion euro for 2015 objectives	N.A. at this stage	Unknown	300 M Euro	Unknown	N.A. at this stage	N.A. at this stage	Unknown
Most important driver(s) to initiate strategy development	Floods in 1993 and 1995	Drought and water shortages	Floods in 1997 and 2002, drought in 2003, institut. and land use changes, EU funding	Floods (1998/2001)	Floods (1998/2001) and droughts, EU policies and funding	Drought and water shortages, institutional changes, ext. funding, pop. dynamics	Drought and water shortages	Threat of extreme climate changes, food security, cap. problems, ext funding
Entirely new management measures?	Yes	No	Partly	Spatial river basin planning with respect to appropriate land use change	Plans for National Drought Committee and a Drought Fund	No	No	New measures being proposed, but not implemented yet
Entirely new physical interventions in river basin?	Yes: retention areas, bypasses, dyke replacements	No	No	No	Replacement of dykes, retention areas	No	No	No, so ar only optimizing existing measures
Structural constraints being recognized/addressed?	Partly	No	Partly	Not specifically	Partly, e.g. changes in regulatory framework	No	No	Minimal > First steps to adress major capacity constraints
Uncertainties being recognized/addressed?	Yes, strategy based on CC scenarios	No	Partly, recognized by CC scenarios, but not addressed in policy	No agreement on CC scenarios and no shared vision on CC adaptation strategy	Partly, but no agreement on CC scenarios	Uncertainties in projections being mentioned as major barrier to adaptation	CC uncertainty only addressed by academics	Partly: recognized by CC scenarios, but not addressed in policy
Changes in the actor network?	To some extent	No	To some extent	To some extent	To some extent	No	To some extent	No
Change in the regulatory framework?	Yes	No	Partly	No	Yes	No	No	No
How does new information enter the policy-making process?	Formal Cie. / informal network	Formal network	Mainly formal, some informal	Only via formal networks	Formal network + informal network	Formal network	Only via formal networks	Mainly formal, some informal
New norms and values?	Yes, paradigm shift from 'fighting against water' to 'living with water', besides more dominant EU norms (WFD, RBM)	EU norms have become more dominant: WFD, RBM planning, stronger involvement of civil society	EU norms have become more dominant: WFD, RBM planning, stronger involvement of civil society	EU norms have become more dominant: WFD, RBM planning, stronger involvement of civil society	EU norms have become more dominant: WFD, RBM planning, stronger involvement of civil society	No	Increasing involvement of civil society	More concern on CC and its impacts + increasing involvement of civil society
Dominant type of learning	Double loop learning + some elements of triple loop learning	SSL (ad-hoc problem solving)	SLL & DLL	SSL (ad-hoc problem solving)	SLL & DLL	SSL (ad-hoc problem solving)	SSL (ad-hoc problem solving)	SLL & DLL
Binary outcome (1 = DLL/TLL)	1	0	1	0	1	0	0	1

Table 6. Key characteristics of climate change adaptation strategies to deal with floods or droughts in eight-case studies. Dark gray indicates a variable dominated by triple loop learning (TLL); Ligh gray indicates a variable dominated by double loop learning (DLL); Dotted field indicates a variable dominated by single loop learning (SLL) (ad-hoc problem solving). The outcomes of these adaption strategies are largely unknown at present. Most of them have only recently been introduced and there has not been enough time to test their appropriateness and effectiveness.

regime has been established it may not yet have achieved its projected outputs (and/or outcomes). Hence, the outcomes of these adaptation strategies remain largely unknown. Most of the strategies have only recently been introduced and there has not been enough time to test their appropriateness and effectiveness. Nevertheless, in this research we have been determining the drivers for developing the adaptation strategies and their initiation points, to be able to compare the timescales and current state of affairs in climate change adaptation in the case studies.

Our first observation in comparing the strategies in different case studies is that there seem to be different responses to drought and flood events: case studies which have recently been confronted with floods have the most advanced strategies, while drought response/adaptation seems to be much slower. These differences might be explained by different risk perceptions (De Hollander and Hanemaaijer, 2003; Neuvel, 2004; Green *et al.*, 2007) and differences in the availability of solutions. We also suggest that these differences might be explained by the nature of the problem itself; whereas flood management is determined by safety concerns, drought management is determined by water scarcity and related problems in the allocation of water resources. Moreover, we argue that the

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threat of floods might be perceived as more threatening and acute than the threat of droughts, as the latter are spread over longer time periods and their consequences are often felt indirectly. For example, in the Netherlands, the risk of drought problems and water scarcity caused by climate change is not acknowledged by all stakeholders (Neuvel, 2004; Huntjens *et al.*, 2010). Nevertheless, perception of risks depends very much on the context; for example, in a river basin where agriculture is dominant and essential for food provision, and drinking water provision is affected, droughts are perceived as very threatening. Going into another potential drought year (in 2010) Uzbekistan is urgently seeking to cope with the expected situation.

Assessing the Dominant Level of Policy Learning

For a better understanding of which type of learning is dominant in each case study it is useful to look in detail at one example: Rivierenland in the Netherlands (Table 7). The Room for Rivers policy is predominantly characterized by double loop learning with elements of triple loop learning (Table 7). The Room for Rivers policy appears to be the only strategy in this comparative study which clearly shows some elements of triple loop learning, such as a change in the regulatory framework, i.e. the spatial planning key decision (PKB, 2006), which consolidates a strategy based on climate change scenarios, and a change in paradigm from 'fighting against water' towards 'living with water'. Moreover, Rivierenland is one of the few cases (also Hungarian Tisza) where there is a clear influence from civil society on policy-making. In the Netherlands this is being reflected, for example, in the '*Advice to the parliament as*

Most important drivers?	Threats of floods in 1993 and 1995
Entirely new management measures?	1) Polycentric governance system was deliberately introduced by means of the National Spatial Planning Strategy (2004); 2) Central/decentral co-management (State as facilitator/controller > objectives and terms of references, Local authorities > advice and development of measures) 3) Pilot projects and programmatic approach (incl. decisions for exchange); 4) Fallback option (alternative of structural protection caused positive pressure); 5) Strong informal process, e.g. by translating knowledge to decision makers, building of trust and supporting transparency; 6) Robust and adaptive process, e.g. by organisational redundancy, explicit role for *regio*, linkages with other issues, flexibility, commitment of decision makers
New physical interventions in river basin?	Retention areas, green by-passes, dyke replacements, "terpen" in Overdiepsche Polder
Structural constraints being recognized/ addressed?	1) Financial constraints: FiKa and Van Lith/Boelhouwer proposal 2) Political: building commitment and creating trust with decision makers by translating knowledge; also trust building between local stakeholders and decision makers 3) Institutional/legal: Key Decision Spatial Planning (2006) > legal mandate
Uncertainties being recognized/ addresed?	1) Scenario-based approaches proved to be helpful in handling risks & uncertainties, e.g. Environmental Impact Assessment & Cost-benefit analysis 2) Experimentation (e.g. impacts of lowering groynes near Beuningen) 3) Transboundary collaboration with '*Arbeitsgruppe*'
Changes in the actor network?	Private parties (by Huussensche waarden), VNO, LTO, ANWB
How does new information enter the policy-making process?	Via formal commissions, via informal network, and via civil society involvement (see "Meer waarden met een robuuste revierruimte", LIRR, 2003)
New norms and values?	Paradigmshift from "fight against water" towards "living with water" / "room for rivers", EU norms (RBM, WFD, public participation)
Dominant type of learning	**Double loop learning + some elements of triple loop learning**

Table 7. Assessment of dominant type of learning in the Room for Rivers policy in the Netherlands. A more detailed description is given by Huntjens *et al.* (2008)

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Case ID	Type of learning which is dominant	Binary outcomes
Rivierenland (Netherlands)	Double/triple loop learning	1
Alentejo (Portugal)	Single (ad-hoc problem solving)	0
Ohre (Czech Republic)	Single/double loop learning	1
Tisza in Ukraine	Single (ad-hoc problem solving)	0
Tisza in Hungary	Single/double loop learning	1
Kagera (Ug/Tan/Rwa/Bur)	Single (ad-hoc problem solving)	0
AmuDarya (Uzbekistan)	Single (ad-hoc problem solving)	0
Upper Vaal (South Africa)	Single/double loop learning	1

Table 8. Summary overview of outcomes being used for mvQCA (based on grey-shaded scaling in Table 6)

regard the PKB Room for Rivers by nine civil society organisations'.[4] This advice was for a large part incorporated in the final strategy. Moreover, the Room for Rivers policy comprises entirely new management measures and new physical interventions. Also, structural constraints and uncertainties are specifically being addressed and dealt with, although there is room for improvement. For example, the rigidity of related policy (e.g. European Water Framework Directive and Natura 2000) – by strictly focusing on objectives – may be a limiting factor to other solutions.

Relationship between Regime Characteristics and the Level of Policy Learning (QCA model)

To supplement the results of the correlation tests, this section introduces results from a method known as QCA, which is based on Boolean comparative logic (Ragin, 1987, 2008). This method compares different combinations of independent variables in relation to a dependent variable, and then simplifies the causal conditions using a bottom-up data reduction process (see Supporting information, Appendix, for a more detailed description of this method).

QCA is particularly suitable for bringing out the full range of causal conditions associated with a particular outcome, and for identifying conjunctures of such conditions (Ragin, 1987, 2008; Rihoux and Ragin, 2008). An essential step in the procedure of a formal comparative analysis using Boolean minimization techniques is the reduction of (qualitative and/or quantitative) data into a set of binary variables. A normal QCA would require the dichotomization of every variable in their absence/presence or low/high, respectively, leading to zeros and ones. However, for an appropriate description of the conditions in the case studies this would be too simplistic and valuable information would be lost, especially as many of the conditions are classified in between 'non-adaptive (traditional) regime' and 'integrated, adaptive regime'. Hence, it is more appropriate to use mvQCA. One of the major consequences of using mvQCA is the loss of parsimony; however, in this case the preservation of valuable and essential information, related to the focus on the transition from non-adaptive towards adaptive regimes, is regarded as more important. Therefore, the results below have weighted averages between 0 and 2 (with '0' as non-adaptive and non-integrated regime; and '2' as adaptive and integrated regime).

The specific objective for using mvQCA in this paper is to identify how different types of interactions among many independent variables in AIWM are related to an outcome of interest (= level of policy learning in river basin management). Our method allows different causal models to lead to a particular outcome, meaning that we are not looking for a blueprint in water management systems.

The truth table (Table 9) provides a summary of both the different combinations of input values (independent variables) and their associated output values (the dependent variable). The output value is defined as the level of policy learning (see Table 8 for the binary output used for mvQCA).

The data reduction process in the Boolean method is designed to reduce the possible combinations of variables associated with the dependent variable by identifying necessary and sufficient causes. Based on the results of seven

[4]Landelijke Initiatiefgroep Ruimte voor de Rivier, 2003, Meer waarden met een robuuste rivierruimte - Veiligheid, Ruimtelijke Kwaliteit en sociaal-economische vitaliteit.

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different models for data reduction (see supporting Appendix) four condition variables have been omitted to reduce the number of simplifying assumptions, resulting in a truth table with five causal conditions (Table 9).

The most important observation at this point is that there seems to be some 'logic' in the data shown in the truth table. For example, when the output is '1' there is a higher density of '1' and '2' condition values, while there is a higher density of '0' condition values when the output is '0'. This observation is consistent with our working hypothesis that a higher level of AIWM shows a different response in coping with floods and droughts than case studies with a lower level of AIWM. The response in the case studies with a higher level of AIWM is different in terms of higher levels of learning, being reflected and/or consolidated in the adaptation strategies to deal with floods or droughts.

Discussion and Conclusions

By analysing the relationship (by using mvQCA) between the level of AIWM and the levels of policy learning (reflected in their adaptation strategies) we conclude that a relatively high score on cooperation structures and information management are causal conditions leading to at least double loop learning in the cases of Rivierenland (Netherlands), Ohre Basin (Czech Republic) and Upper Vaal (South Africa). In the case studies where these conditions are less developed, e.g. in the Alentejo Region (Portugal), AmuDarya (Uzbekistan) and countries of the Kagera Basin, the strategies are characterized by single loop learning (ad hoc problem solving).

Better integrated cooperation structures are characterized by the inclusion of non-governmental stakeholders, governments from different sectors (supporting horizontal integration) and government from different hierarchical levels (supporting vertical integration). Advanced information management is characterized by joint/participative information production, a commitment to dealing with uncertainties, broad communication between stakeholders, open and shared information sources, and flexibility and openness for experimentation. As such, advanced information management may be considered the lubricating oil within cooperation structures, and is considered a crucial prerequisite for facilitating learning processes, building trust and supporting cooperation.

An important conclusion based on our formal comparative analyses is that better integrated cooperation structures and advanced information management are the key factors leading towards higher levels of policy learning in river basin management. Higher levels of policy learning are being reflected and/or consolidated in more advanced adaptation strategies for dealing with floods or droughts. These advanced adaptation strategies are characterized by: (1) a robust and flexible process; (2) polycentric, broad and horizontal stakeholder participation; (3) climate change scenario analyses; (4) risk assessments; (5) high diversity in management and physical interventions; and (6) dealing with structural constraints of the management system itself.

Moreover, the above conclusions support our initial assumption that effective AIWM is able to facilitate a change in strategy, as being an adaptation to climate change. As such, there is a reciprocal relationship between AIWM and the development of adaptation strategies. Moreover, our assumption is confirmed that this relationship is reciprocal only in a situation of bottom-up governance, including real participation of non-governmental stakeholders, but also from different government sectors, lower levels of government and downstream stakeholders. This bottom-up process is emerging from partnerships and networks (Geels *et al.*, 2004).

Case ID	Coop	Pol	Inf	Fin	Ris	Output
Rivierenland	2	1	2	1	1	1
Alentejo	0	0	0	1	1	0
Ohre,Upper Vaal	1	1	2	1	1	1
Ukraine	0	0	1	0	0	0
AmuDarya	0	0	0	0	0	0
Kagera	0	1	1	0	0	0

Table 9. Representative truth table with five causal conditions. Coop, cooperation structures; Pol, policy development & implementation; Inf, information management; Fin, finances and cost recovery; Ris, risk management

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While addressing the importance of social leaning and participation processes we also argue that these extensive processes should only be initiated when: (1) different stakeholders depend on each other to reach their goals, in particular when knowledge is incomplete or knowledge is dispersed amongst different persons/stakeholders; (2) there is no agreement on the problems at stake; and (3) the issues are important enough for the stakeholders to invest the necessary time (and therefore money). Adapting to climate change in this case means a commitment to dealing with complex, unpredictable and dynamic change.

An important hypothesis in the concept of social learning is that information management and social (cooperation) structures are interlinked (Pahl-Wostl & Sendzimir, 2005), which corresponds to the socio-cognitive theory of information systems (Hemingway, 1998). Hemmingway emphasizes the impacts of the presented information on learning and action, and the centrality of the selection and organization of information to the nature of organizational forms.

Our research confirms that information management and social (cooperation) structures are interlinked in the management systems under consideration. This interdependency can be described as the socio-cognitive dimension of water management regimes, which is defined in this paper as the integrated cognitive and social properties of complex governance systems and its supporting processes (e.g. social learning, stakeholder participation and content-related collaboration). The socio-cognitive dimension is an essential emerging property of a water governance system, depending on a specific set of structural conditions. In particular, better integrated cooperation structures and advanced information management are structural conditions leading towards higher levels of policy learning. This socio-cognitive dimension is inherent to the adaptive capacity of water governance systems, and in systems where this dimension is absent or less developed there is reduced capacity for developing advanced adaptation strategies.

The importance of the socio-cognitive dimension is directly related to the fact that climate change adaptation is a so-called 'wicked' problem, characterized by complexity, conflicting interests and an unpredictable future. Hence, to achieve institutional adaptation, certain elements need to be focused upon, including adequate access and distribution of information, collaboration in terms of public participation and sectoral integration, flexibility and openness for experimentation.

In contrast to conventional conflict-orientated theories this research provides evidence that learning is an important source (if not the key source) of policy change (Huntjens, *et al.*, 2008). Within conflict-orientated policy theory, the nature of the mechanism or agent of policy change and the role of knowledge in that process remains unclear (Castles, 1990). As, for example, Folke *et al.* (2005) have pointed out, social learning is needed to build up experience for coping with uncertainty and change. They emphasize that 'knowledge generation in itself is not sufficient for building adaptive capacity in social-ecological systems to meet the challenge of navigating nature's dynamics' and conclude that 'learning how to sustain social-ecological systems in a world of continuous change needs an institutional and social context within which to develop and act'. Knowledge and the ability to act upon new insights are continuously enacted in social processes (Geels *et al.*, 2004; Folke *et al.*, 2005). Our formal comparative analysis suggests that the social network of stakeholders is an invaluable asset for dealing with change.

We can also conclude that management regimes characterized by a high level of top-down governance are dominated by lower levels of learning (= single loop learning/ad-hoc problem solving), such as the management regimes in the Alentejo Region, AmuDarya and Kagera Basin. This lower level of learning is being reflected and/or consolidated in less advanced adaptation strategies. Also, the Hungarian part of the Tisza is characterized by top-down governance, although they have managed to develop an advanced adaptation strategy [new Vásárhelyi Plan (VTT), 2003], probably caused by the existence of a shadow network in this specific example. The VTT is an excellent example of double loop learning and of a modified flood defence strategy by local actors and research institutions. However, the current implementation of this plan is seriously hampered, as the centralized management system has not managed to find agreement between different Ministries on allocation of the necessary (financial) resources. In other words, a high degree of top-down governance and centralization seems to be a serious limiting factor in this case study as well.

Especially in river basins such as the AmuDarya, Orange, Guadiana and Nile, a higher frequency and intensity of droughts, in combination with higher temperatures, pose serious threats to food security. The management system in the Orange Basin is already more advanced in this respect as it shows a higher level of AIWM and more advanced adaptation strategies. However, capacity in the region is rapidly becoming a serious limiting factor (Huntjens *et al.*, 2008). This is particularly evident in South Africa where the challenge of implementing water

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resources management plans is so large, but there has been a serious loss of skills. Capacity building programmes are on the agenda of the South African government Department of Environmental Affairs and Tourism and the Department of Water Affairs and Forestry, but it has not been sufficient to compensate for the continuing loss of skills. Hence, it is important to recognize that the ability to adapt in the individual countries may depend on the availability of financial and human resources, technologies, levels of education, available information, suitable planning and the overall infrastructure. In general, the economically and socially more developed countries have disproportionately greater potential for adaptation than developing countries. For example in the Nile there is great willingness to be adaptive, but there are a number of structural constraints mentioned by the majority of experts in this case study: (1) problems in organizational set-up related to horizontal and vertical integration; (2) lack of human capital (people skilled and educated for certain tasks); (3) low level of awareness among decision-makers on climate change issues: how will climate change, what will the impacts be, which adaptation is needed?; (4) lack of adequate financial resources for adaptation; (5) lack of information and of exchange among the relevant actors; (6) spatial and temporal uncertainties associated with climate change projections. The central thread being recognized in these structural constraints is again a combination of cooperation structures and information management.

What is also important is that, based on our formal comparative analysis, the conditions of policy development and policy implementation, finances and cost recovery, and risk management, do not play the most central 'causal' role in explaining the level of policy learning (see supporting Appendix). This observation suggests the need to investigate further whether these conditions may be considered as outcomes of an adaptation strategy. In that case, it would support our assumption that the relationship between the management system and its adaptation strategy is reciprocal, as the strategy itself influences the management system. This means that there could be many non-linear feedback loops within the management regime itself, and the regime is in that sense creating its own enabling environment. We argue that this is the essence of triple loop learning. In other words, information management and cooperation structures seem to be crucial for moving towards structural change, and they support innovative approaches which then will encounter structural constraints which need to be overcome. This would also imply that the sole focus on mobilizing finances is not leading to effective and or efficient outcomes. The essence of triple loop learning is being observed in regimes with a higher level of AIWM where the formal institutional setting is being altered by the demand for governance as regards (new developments in) water-related problems, such as the impacts of climate change. Examples include the Dutch National Water Agreement (Ministerie van Verkeer en Waterstaat, 2002), leading towards the start of implementing the Room for Rivers policy (PKB, 2006). Another example is the Hungarian National Drought Strategy (2004), which was developed based on severe droughts in Hungary over the past decade. Nevertheless, the complex interdependency as described above is only addressed to a limited extent in this research, but should be taken into account by future research activities. For analysing dynamic or transitional systems, in particular, it is essential to conduct longitudinal research.

It is not yet clear to what extent our findings are generalizable to adaptation in other sectors than the water sector. However, being able to deal with complexity and uncertainty is certainly relevant for many sectors, and as such the insights derived from this research are relevant for complex policy problems in different sectors. Having said this, the insights and conclusions of this research need further testing and elaboration. In particular, issues of generalizability and effectiveness of strategies deserve further exploration. The key factors for policy learning proposed here arose from explicit consideration of water management challenges in the context of a changing climate, in particular related to floods, droughts and water scarcity. These specific climatic hazards have been selected because they are the most common extreme events (IPCC, 2007; World Water Development Report, 2009). Dealing with them effectively will undoubtedly have a positive impact on the food and agricultural sector as well as other economic activities, and will substantially reduce the negative impacts of climate change on human health (WHO, 2009).

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