Assessing Climate impacts on the Quantity and quality of WAter

Deliverable D.Policy.3: Options for adaptive capacity, policy and governance recommendations for each basin – month 56

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Exploring options for adaptive capacity, policy and governance recommendations for each basin: Water, Resilience and the Law - From General Concepts and Governance Design Principles to Actionable Mechanisms

1. Introduction

Laws, regulations, rights and other 'rules' associated with water resources are fundamentally important procedural elements of any governance system. Climate change has significant ramifications for water law and governance; however, there is strong evidence globally that legal regulations have often failed to protect environments or promote sustainable development in this shifting context (Ebbesson, 2010; Ostrom, 2005). Within the resilience literature on social-ecological systems, one proposed cause is that while legal systems have tended to be fragmented, principle-based and rigid, the ecological systems which they are constructed to govern tend to be inter-connected, non-linear, complex and dynamic (Garmestani et al., 2009). Another issue has been the challenge of reconciling the scientific quest for truth (i.e. continual revision and re-questioning) within legal systems that are designed to provide predictability, security and finality (e.g. conflict resolution, legal codes).

To date, law and regulation relating to natural resources management have tended to be based on preservation and restoration paradigms, which have assumed largely that ecosystem change is both predictable and reversible (Craig, 2009). While in many areas the development of environmental law has provided for increased protection of the environment over the 20th century, there has been growing criticism of the structure and rigidity of the preservation paradigm used to address direct human impact-related problems (notably point and diffuse source pollution) of the mid-20th century (Verschuuren, 2007). Some scholars have suggested that these principles are no longer adequate for the legislative challenges that relate to complex, cross-scale and interacting social-ecological systems (e.g. climate related challenges) (Shellenberger and Nordhaus, 2004) because of their linkages to assumptions of stationarity and uniformitarianism (Ruhl, 1997). Therefore, while current regulation and control may be appropriate to the environmental quality challenges for which much environmental law was designed, the appropriateness of prior approaches may not be as relevant for the interlinked, unpredictable and potentially irreversible impacts of global environmental change (Craig, 2009; Ruhl, 1997).

The literature to date has begun to address how resilience concepts can be applied to thinking about the law as its own complex adaptive system (Ruhl, 2012) and the capacity of different facets of the legal system to accommodate and foster social-ecological resilience (Barnes, 2013; Benson, 2012; Garmestani et al., 2013; Green et al., 2013). Many of the contributions to date have proposed a number of generalised concepts for addressing the challenge of balancing predictability and rigidity of legal frameworks with the complexity in social-ecological systems against the flexibility required within science based decision making (Cosens, 2010; Craig, 2009; Hurlbert, 2009; van Rijswick and Salet, 2012; Westley et al., 2011). While this represents an important starting point for

framing the challenges of aligning institutions and the complex adaptive system of the law itself (Ruhl, 2012) with the complex non-linear systems they govern, more research is needed to identify key measureable legal and institutional features (Ebbesson and Hey, 2013) that might promote more resilient water governance and management in the face of climate change, thus presenting more tangible solutions to lawyers, policy makers and decisions makers.

This study aims to contribute to the advancement of the discussion on the role of specific aspects of the legal system in order to establish more resilient water governance and management systems. Thus, we focus more specifically on exploring different legal mechanisms in a range of water governance contexts that provide insights on the challenges and opportunities for enhancing resilience through the law. This study is therefore less concerned with the resilience of law or the law itself as a complex adaptive system, and more interested in features of the law that might allow water resources governance and management to enhance society's resilience to climate variability and climate change impacts on water resources and ecosystems.

2. Background: Resilience to Climate Change Impacts on Water Governance

Resilience is defined as a measure of the amount of perturbation a linked social-ecological system (SES) can withstand and still maintain the same structure and functions (Holling et al., 2002; Walker et al., 2004). A persistent system will be able to withstand pressures and change (this can be both positive and negative), while a system's response to change reveals its capacity to adapt (Barnes, 2013). In the context of numerous pressures (exploitation, pollution, climate change, climate extremes) on water resources, there has been significant focus on attempting to identify factors within water governance and management that may enhance or reduce the resilience of the social-ecological systems, especially in terms of its adaptive capacity (the ability to prepare for and respond to variability, change or surprise in the state of an SES, closely linked to robustness, adaptability and coping (Chapin et al., 2009; Smit and Wandel, 2006).

In the past decade, there has been a growing body of work on the needs and requirements for adaptive capacity, adaptive management (where each management step is an opportunity for further adaptive learning), adaptive governance (collaboration and cooperation across different levels of government and agencies, often with overlapping authority, non-governmental and individual action), and adaptive and integrated water resources management (IWRM) in social-ecological systems (Engle and Lemos, 2010; Folke et al., 2005; Gupta et al., 2010; Hill and Engle, 2013; Huitema et al., 2009; Pahl-Wostl, 2007; Pelling and High, 2005). This has led to much of the literature identifying traits of adaptive governance and management that enable a system to manage and cope with increased uncertainty in dynamic systems and changing social-ecological baseline conditions: including *flexibility* in social systems and institutions to deal with change; *subsidiarity* and *connectivity* (openness of institutions providing for extensive participation, effective multi-level governance); *iterativity* (social structures

that promote learning and adaptability without limiting options for future development) (Cosens, 2013; Ebbesson, 2010; Ebbesson and Hey, 2013; Folke et al., 2005; Huitema et al., 2009).

Adaptive approaches are intended to enhance resilience across multiple temporal and spatial scales, rather than leading to adaptations that might increase vulnerability and thus degrade resilience at certain temporal and spatial scales (Hill and Engle, 2013). Therefore since SESs are inherently dominated by cross-scale interactions, the rules for enabling adaptation in SESs need to avoid social versus bio-physical boundary mismatches and temporal lock-ins that can increase vulnerability to climate change impacts (Cosens and Williams, 2012; Walker, 2012). Armitage (2013) discusses the importance of disentangling the resilience of the governing system (water laws, policy, institutions) and that of the system that is governed (i.e. rivers, groundwater, riparian ecosystems), noting that '*the resilience of the governing system is not necessarily positively correlated with the resilience of the system to be governed*' (p 1).

Law, and the legal system, plays an important role in water management and governance, in its function as an instrument to set and achieve social, economic and environmental objectives (Ebbesson and Hey, 2013). The legal system, laws, regulations, property rights, set the rules that shape and define the implementation and procedures of water policy, governance and management (Cosens, 2013). Law is therefore one of many factors that can affect, positively or negatively, the capacity of a social-ecological system to cope with a range of impacts and changing conditions (Ebbesson and Hey, 2013). In contrast to ecological systems, social systems often adapt through deliberative process, with the legal system playing a role in choosing whether or not to foster or prioritise social-ecological resilience through processes such as legislative reform (Barnes, 2013; Cosens, 2013; Folke et al., 2005). In this way, the law can also be seen as the rules for enabling change to the rules that might allow for temporal or spatial scale mismatches to be better addressed (Walker, 2012).

Different facets of the legal system govern different aspects of the implementation of law, regulation and the management of water resources. Substantive laws govern what is managed, who is regulated, and the goal of that management or regulation (Cosens, 2013). In turn, administrative law governs how these functions are implemented, including the process of decision making by the government or another governing body (Cosens, 2013). Property rights define the ownership, disposition, use, management, income rights, transmissibility, security rights, as well as duties such as non-harmful use of water resources (Honoré, 1961 in Barnes, 2013). Formal or informal institutions (e.g. state, courts or community) often have an important role in enforcing, monitoring and protecting property or use rights.

3. Aims and Approach

This article aims to contribute to and advance the development of the nascent body of literature on resilience and the law, by identifying and presenting tangible and

applicable features required in law or institutional structures for enhancing the adaptability of water law and policy to climate change impacts. This paper takes a similar approach to a number of other articles in this body of literature (Barnes, 2013; Cosens, 2013; Ebbesson, 2010; Ruhl, 2012), in its exploration of the conceptual and empirical challenges concerning the tensions and relationship between resilience and the law. The conceptual discussion is underpinned with a broad range of empirical examples taken from a set of jurisdictions that are representative of a wide variety of water governance regimes, including both domestic laws as well as regional regimes (e.g. Water Framework Directive). These examples serve to illustrate how the tensions and challenges discussed play out in operation, and thus assist in the development of the framework presented in the discussion section.

An initial review of the relevant indicators and principles from adaptive and integrative water governance and resilience based adaptive capacity literature was undertaken and synthesised (*see Table 1*). Drawing on this review, the authors identified and explored a set of best practice examples of how governance frameworks have applied these principles to different extents and thus integrated uncertainty, complexity and changing baseline conditions into legal frameworks. These mechanisms were then evaluated in relation to the broad climate change impacts on freshwater resources and ecosystems to ascertain the suitability of the best practice examples for the kinds of change and uncertainty that climate change implies.

Table 1: Overview of determinants from the resilience, adaptive capacity, adaptive governance and adaptive (co-)management literature grouped into the four core principles.

Principles	**Associated Determinants**
Iterativity Generation, processing and application of knowledge.	Reflexive law (Scheuerman, 2001).
	Monitoring capacity; Information and knowledge sharing; Use of traditional and local knowledge (Folke et al., 2005; Olsson et al., 2004; Ostrom, 2007).
	Measured stability (Cosens, 2010).
	Iterativity in laws, plans and institutions to deal with uncertainty (Garmestani et al., 2009; Keeney and McDaniels, 2001; Pahl-Wostl et al., 2007a).
Flexibility Willingness and capacity to adjust.	Willingness and ability to adjust; Funds for responding to change and action (Engle and Lemos, 2010; Iza and Stein, 2009).
	Principled flexibility (Craig, 2009).
	Capacity for learning and response (Huntjens et al., 2011).
Connectivity Connections and networks across sectors and scales for mobilisation, cooperation and collaboration.	Integration across geographical, sector and governance scales (Engle et al., 2011; Pahl-Wostl et al., 2007b).
	Information and knowledge sharing; networks for managing conflict; fostering cooperation; combining knowledge (Folke et al., 2005; Olsson et al., 2004b).
	Connectivity; flexible social networks; bridging and boundary organisations (Engle and Lemos, 2010; Olsson et al., 2007).

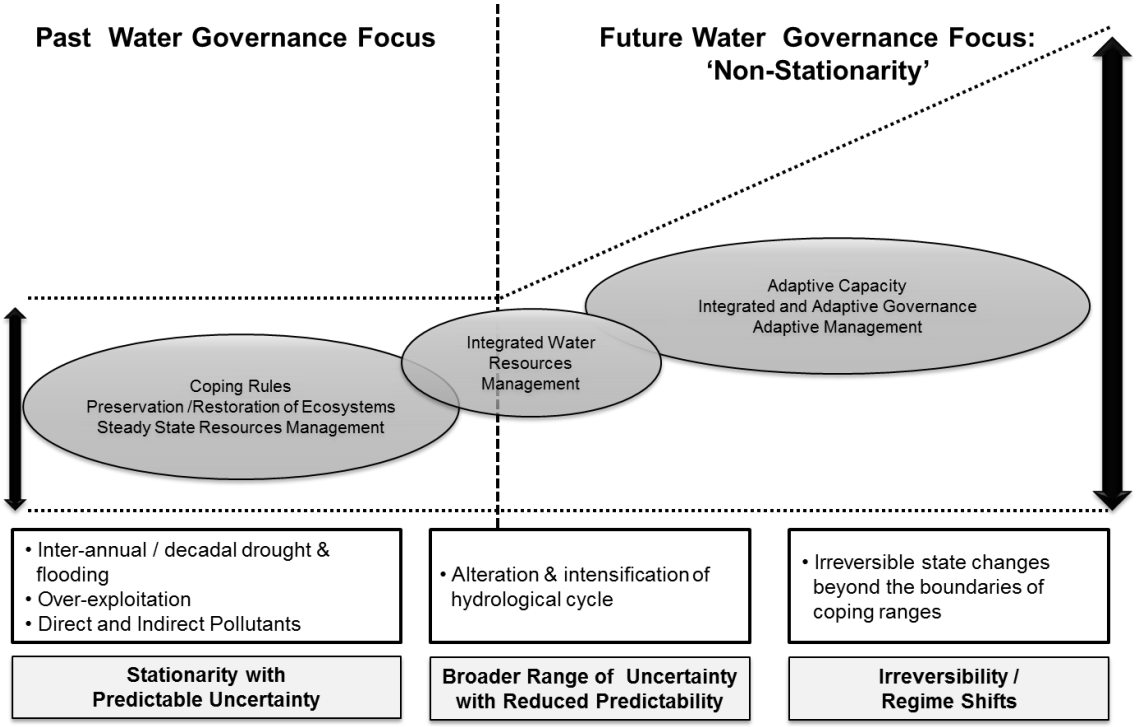
	Vision, innovative leadership and trust (Olsson et al., 2006; Tompkins and Adger, 2005).
Subsidiarity Implementation at lowest or most suitable level.	Ecological based units of decision making (Berkes and Folke, 2001; Huitema et al., 2009).
	Polycentric, horizontal regimes with broad stakeholder participation (Huitema et al., 2009; Pahl-Wostl et al., 2007a).
	Living law (Hurlbert, 2010).

4. Reconciling Resilience and the Rule of Law

4.1 Challenges of Scale: Spatial, Temporal, Magnitudes of Variability and Uncertainty

Figure 1 depicts the increasing rate, magnitude and scale of change and uncertainty that underlines the need for legal regimes to shift away from notions of 'predictable uncertainty' (Matthews et al., 2011) and 'stationarity'(Milly et al., 2008). The left side of the graph represents the focus of water governance for the previous 150 years, on which many legislative frameworks and management techniques are based. The right hand side of the figure represents the future focus of water governance with non-stationarity and increased uncertainty due to the breadth of projected emission and associated climate warming scenarios (IPCC, 2007). Climate change projections embody a broader range of uncertainties; and more extreme levels of warming may lead to irreversible changes in state (e.g. reduced runoff contribution from frozen water stores [glacier and snow melt], depletion of fossil groundwater aquifers) and greater system variability (e.g. more extreme floods and droughts) that may lie beyond the boundaries of past and present coping ranges of water governance and management regimes (Min et al., 2011; Smit and Wandel, 2006; Wilby et al., 2010; Yohe and Tol, 2002). This underlines the need for researchers and practitioners in water resources management and governance to better understand adaptive processes that seek to embrace, rather than control uncertainty.

Figure 1: The shifting focus of water governance: The left side of the graph represents the phase of water governance during the last 150 years, while the right hand side represents the future phase of water governance under climate change and non-stationarity. The black arrows on the left and right depict the range of uncertainty associated with the two different water governance phases, underlining the need for legal scholars to better understand adaptive processes that seek to embrace, rather than control uncertainty.



It is important to note that the diagram does not seek to represent inter-annual or seasonal hydro-climatological variability but rather changing water governance foci. We recognise that different hydro-climatological regions have markedly different levels of climate and water resource base variability (tropics vs arid regions vs poles) that have influenced historical adaptation strategies. This diagram does not seek to encapsulate this concept, rather it illustrates (for any hydro-climatological region) the shift in water governance requirements that may result from non-stationarity, greater uncertainty and shifts in the hydro-climatological/ water regimes.

4.2 Resilience Principles and the Law

There has been growing interest amongst some legal scholars on the ability of the law to support more adaptive and flexible frameworks to meet the challenges discussed above. This section will review the insights to date on resilience and the law, in conjunction with the key principles proposed in the adaptive governance and adaptive capacity literature as being critical for coping with uncertainty (Ebbesson, 2010; Folke, 2006): *flexibility* in social systems and institutions; openness of institutions; effective multi-level governance promoting *connectivity* and *subsidiarity*; promotion of *iterative* learning and adaptability (*see Table 1*).

Craig (2009, p23) suggests that '*both regulatory goals and the legal mechanisms for accomplishing them will have to be centred on the concept of change itself*'. Legal scholars have tended to focus on the potential juxtaposition between the law and resilience as a complex challenge of balancing the search for stability and predictability in legal frameworks with the complexity in social-ecological systems and the flexibility

required within science based decision making (Barnes, 2013; Cosens, 2013; Craig, 2009; Ebbesson, 2010; Ruhl, 2009). Craig (2009) and Cosens (2013) propose that concepts such as 'principled flexibility' (Craig, 2009) or 'measured stability'(Cosens, 2013) could be useful in addressing the complex inter-relationship between the legal framework (defined by normative texts and fixed, predictable rules) and dynamic ecosystems. They propose that these concepts could allow the law to adjust to continual transformation by enabling the measured integration of science for more effective conflict resolution.

'Principled flexibility' would require law and environmental management goals to iteratively reflect shifting baseline hydrological or ecological conditions (e.g. exemption clauses based on continuous informational inputs). In the case of the USA, this would necessitate potential amendments to administrative law (the rules that guide government agency rule making) to ensure that judicial review (the process by which legislative and executive actions are subject to review by the courts) would facilitate a process of review and adaptability (Craig, 2009). Cosens' (2013) concept of 'measured stability' refers to the integration of adaptive processes through the utilisation of measured timeframes based on both the economic and ecological criteria, thus focussing more heavily on the sound scientific basis to develop the legal toolbox.

Garmestani et al (2013) point to the importance of matching institutions to the appropriate scales in the interest of balancing stability with flexibility, underlining the important role legislation and regulation play at different scales of governance in adaptive and integrated resource management, particularly in the case of water resources governance (Ebbesson, 2010). One of the aims of IWRM is in fact to retain flexibility in water management systems, by relegating different management mechanisms (monitoring, regulation etc.) to more '*dynamic parts of the legislative system*' (GWP, 2000, p38), such as regional and local regulations and ordinances. Hence, the law can be seen as more dynamic and less rigid than many scholars would suggest (Hey, 2010).

Not only is the word of the procedural law less certain and inflexible than often presented, but substantive law (in terms of property rights and individual rights) is also subject to renegotiation and development (Langlet, 2010), as observed by the gradual development of western water law in the USA as well as the gradual development of English water law to take account of developments in use and demand patterns (Getzler, 2004; Scott and Coustalin, 1995; Tarlock, 2012). Barnes (2013, p12) notes that the '*defeasible and dynamic nature of law lends itself particularly to adaptation*' in particular pinpointing that the high degree of flexibility, variety and contextual application within domestic property regimes is well-suited to the maintenance of optionality for sustaining resilience strategies. However, while there may be a greater potential to take account of social-ecological complexity and uncertainty in legal frameworks than first apparent, achieving this operationally, and in shorter time frames, is a major and unresolved challenge (Langlet, 2010; McIntyre, 2010).

With regards to substantive law, Craig (2009) highlights the importance of giving meaningful weight to public rights and values in private property to address the challenges governments may face in addressing the impact of climate change on what the public perceives as 'absolute' private property rights. Hey (2010) states that legal certainty does not necessarily have to be non-adaptive, suggesting that a blend of procedural certainty and changing substance may address the challenge of the shifting baselines that rights and laws must accommodate. Some jurists have argued that less predictable uncertainty may in fact necessitate more stable and rigid legal structures, but with more flexible content, as well as flexible instruments to combine both rigidity and flexibility (Hey, 2010). This refers to instruments that balance the regulatory and enabling function of the law (i.e. the law as goal oriented), with a process for reviewing and revising those goals once the specific baselines upon which they are set shift.

Likewise, the development of stable and predictable structures at higher levels (law, regulation, government institutions) may allow for greater flexibility and experimentation at lower levels (Cosens, 2013; Garmestani et al., 2013). Therefore, the law could also be framed as stability within change, as opposed to stability versus change, placing greater attention on finding the right balance between structured and reflexive aspects of the legal framework to enable adaptive capacity within water governance regimes. However, many of these generalised concepts and design principles lack the requisite clarity and level of detail required for operationalisation by policy makers and legislators.

The literature on resilience and law has thus pointed to a number of properties that legal systems should demonstrate in order to support the attributes of resilience and adaptation within the systems they govern, which draw on the attributes of adaptive and integrative governance and management detailed in section 2. Thus, drawing on both the legal principles discussed above and the different principles and determinants within the adaptive and integrative governance and resilience-based literature on adaptive capacity (*see Table 1*), four main 'guiding principles' have been discerned for the purposes of the following discussion: iterativity, flexibility, connectivity and subsidiarity.

- *Iterativity* encompasses those principles relating to the generation, processing and application of knowledge.
- *Flexibility* comprises those relating to the willingness and capacity to adjust to changing conditions and new information.
- *Connectivity* covers principles concerning the networks and connections across sectors and scales for mobilisation, cooperation and collaboration.
- *Subsidiarity* relates to the principles concerning the implementation of policies and provisions at lowest or most suitable level.

These principles are used in the following section to frame our analysis and discussion of current best practice. The review of empirical examples used in the next section serve to underpin the conceptual discussion and review of the literature with a broad range of

examples of water law and regulation taken from different jurisdictions and geographies in order to illustrate the opportunities and challenges for operationalising resilience based principles in different facets of the law.

5. Providing Best Practice Examples

Water law frameworks have historically accommodated inter-annual fluctuations in the availability of water in a number of ways. In the western USA, the prior appropriation system accords priority to those holding the oldest registered use rights, with junior appropriators, those who hold the most recent rights, bearing the brunt of shortages in lean years. With respect to irrigation, head farmers may continue to use something approaching their normal consumptive rates with tail farmers receiving the remainder, if any (for example see Ostrom, 2002). Alternatively, farmers may legally respond by supplementing their surface water rights with groundwater, as is the case in parts of Spain for instance (Hendry, 2011).

In the case of water use rights, frameworks for managing their allocation have developed to take account of prevailing priorities of use and property rights, but as discussed in Section 4.2, they have not remained static over time (Getzler, 2004; Scott and Coustalin, 1995). Where prior-appropriation regimes are in place, for example, the property rights and use needs justified the establishment of the system, but the framework developed over time to accommodate to some extent the needs of water-dependent ecosystems (Neuman, 2004), permitting some flexibility in its application to avoid manifestly unreasonable outcomes (Tarlock, 2012). Although these were designed to accept changing resource availability, emerging public policy requirements such as the demands of social equity and environmental protection have exposed limitations in some of the mechanisms applied to address inter-annual variability.

Thus the increased uncertainty expected under climate change is not of itself especially problematic for systems like prior appropriation or riparian rights regimes in their ideologically pure forms; but the increasing importance afforded by policy to ensuring that use patterns are sustainable over the long-term makes climate change-induced shifts in water availability much more difficult to manage through existing frameworks than it may have been in the past. The other critical factor to note at this point is that the increasing focus on long term resource sustainability, coupled with the awareness of impending changes in the resource base and improved modelling and projection techniques mean that water managers and policy makers are now having to take account of future demand in a way that they did not and could not in the past.

In the light of the above, the following section seeks not to provide an exhaustive assessment of responses to these demands as manifested in practice around the world, but limits itself to highlighting examples of particular approaches derived from countries where the legal frameworks for the management of water have been recently overhauled or revised, or which are indicative of certain legal traditions (Caponera, 2007; La Porta et al., 2008). It will also serve to illustrate the factors that influence the

success or otherwise of these approaches. Very broadly, there is a worldwide move to modify entitlements to water use such that they are no longer immutable or absolute, thereby allowing governments to take greater account of public interest considerations (including expected trends in resource availability) in the management of water use rights. This approach normally permits variation of the terms of use rights and is often, though not exclusively, associated with fixed term use rights rather than the perpetual rights issued in the past. Finland is a notable example where rights of use are issued without time limit but are variable (Allan, 2011).

One of the key mechanisms adopted to ensure that use rights remain commensurate with longer-term changes in an iterative manner in resource availability is a ***review process***. This is evident in the South African and Tanzanian contexts and also in the wealthier European Union. In South Africa, holders of water use rights are not guaranteed that their licence will yield the water they are entitled to (National Water Act 1998, s.31). In addition, these licence holders can expect their fixed term rights to be reviewed every five years at least (NWA 1998, s.28) and varied in the event that allocated rights exceed the amount needed to ensure that basic human needs are satisfied, aquatic ecosystems protected and international (transboundary) obligations fulfilled (NWA, s.49).

In the European Union, the 'programmes of measures' that are established to achieve environmental objectives under the Water Framework Directive (European Parliament, 2000) (WFD) must be revised every six years (WFD, art.11 [8]). In line with the principle of subsidiarity, member states must put in place use rights frameworks that will allow them to adapt accordingly, although the WFD does not itself attempt to prescribe the nature of those frameworks. Instead, it establishes certain administrative requirements (e.g. basin management, cost recovery for water services and stakeholder involvement in the planning process) and then sets ecological, chemical and quantitative standards that states must adhere to using whatever means as will meet these requirements. Because the WFD is focused on protecting and improving ecological quality of water bodies in particular (WFD, art.4), in line with the principle of connectivity, it seeks to control land and water use management in combination with basin-specific ecological capacity.

Another example of the iterative process of review may be found in Tanzanian water resources management plans, which must be reviewed every 3-5 years (Water Resources Management Act 2009, s.31 [4]). However, Tanzania is a complex example, since a number of the key mechanisms that distinguish the South African legislation in terms of protecting equity and ensuring that allocated rights are commensurate with changing resource availability are absent. For example, permits in Tanzania can be of unlimited duration and unspecified in volume. Considerations for iteratively reviewing and varying permits are based on the volume available for satisfying existing permits rather than environmental requirements. Basin boards can unilaterally impose volumetric and temporal restrictions on permits (in line with subsidiarity). In addition,

the 'reserve' that is set aside for human and environmental needs is dependent for its establishment on a separate 'classification of waters' (s.33), which in itself is not mandatory (s.32[1]).

Differentiation in the level of detail at varying geographical and governance ***scales*** is reflected by practice at the national level. As noted above, greater levels of dynamism may be introduced as the scale gets smaller, thereby allowing management to take better account of local circumstances (subsidiarity) in a spatial sense as well as a temporal one (enabling flexibility for future shifts in the resource base). Crucially, framework legislation such as the WFD must facilitate provision of more local legislation without hindering management through the imposition of locally inappropriate standards. In Scotland, the broad principles of water management, adhering to those set out in the WFD, are contained in primary legislation (WEWS 2003), with the means of implementing those principles being generally set out in secondary legislation (e.g. Water Environment [Controlled Activities] Regulations 2005). It is noteworthy that these regulations have been amended a number of times since their original promulgation and this highlights the greater degree of flexibility inherent in secondary legislation. At the opposite end of the spectrum, in Chile, changes to the 1981 Water Code have been made (in 2005), but not without great difficulty and over a protracted period of time (see also Ostrom (1990) on the nesting of rules).

As part of the move towards limiting the relative absolutism of earlier water use rights, based on land ownership for example, governments have been increasingly introducing ***permit systems***. These permits, or administrative authorisations, are regarded as a form of property right (Hodgson, 2006; Sax, 1990), but these are not inviolable and do not imply ownership of the resource itself (thus being more flexible to shifting hydro-climatic conditions). Critically, these can allow regulators to vary use rights not only in response to scarcity, but also in advance of expected changes. The review processes referred to above can facilitate this, subject to a degree of stakeholder approval. In the examples given, South African variations are subject to restrictions in the interests of equity and in the EU the river basin management planning process is bound by detailed stakeholder review mechanisms. For permit systems to succeed, they must apply to all water resources (in line with connectivitiy). They are undermined when more unaccountable private water use rights are allowed to remain and co-exist, as is the case in Spain and in Chile.

Australian practice has been at the forefront of efforts to accommodate shifting water resource variability in a legal context. The National Water Initiative (NWI) specifically apportions the future risk of reduced water availability across a range of actors (NWI, paras 48-51). The State of Victoria allocates water use entitlements as a share of the overall resource, thereby ensuring that scarcity is more equitably apportioned across user groups, and its planning framework addresses the projected situation in 50 years' time (in line with both connectivity and flexibility). Parts of Australia also allow trading

of water use rights, although this is connected to the question of availability rather than variability, and does not address longer term planning issues (McKay, 2012).

States are increasingly recognising the need for the establishment of national databases of water uses. This is perhaps best observed in the Australia Bureau of Meteorology's General Purpose Water Accounting, part of the NWI. The aim of these accounting practices being developed on cross-border basins and between states is expressly related to planning and management in the NWI (COAG NWI 2004), and demands the existence of a highly sophisticated monitoring network capable of generating data needed, in part for the purpose of ensuring that the public has confidence in the states' management of water resources (Allan, 2012). Comparable efforts have been under way in the EU as part of the implementation of the WFD, specifically the detailed monitoring standards required under the Directive's annexes and the establishment of the Water Information System for Europe (WISE). Public availability of these data is a key element of both systems, and mechanisms for ensuring that data are available and accessible are integral components of the current world standard: the Aarhus Convention (UNECE, 1998).

The examples given above often cross-cut the different guiding principles, but Table 2 provides a consolidated overview of the key actionable mechanisms from the frameworks discussed above in relation to each guiding principle.

Table 2: Specific and actionable governance mechanisms identified for applying adaptive governance principles and balance flexibility of adaptive approaches with requisite predictability of legal structures.

Adaptive Governance Principles	**Actionable Governance Mechanisms** Policy, Legislation, Regulation, Property Rights
Iteratively *Generation, processing and application of knowledge.*	• Time-bound review periods with potential reallocations. • Varied rights (subject to environmental and social conditions) and permit systems. • Administrative requirements in separate secondary legislation. • Review periods for fixed term rights (subject to social and ecological obligations).
Flexibility *Willingness and capacity to adjust to changing conditions and new information.*	• Time limited licencing so regulators can vary use rights in advance of expected changes. • Risk diversification through use entitlements as share of overall resource. • Emergency provisions and powers during drought and flood events. • Risk apportionment and diversification across variety of actors. • Variable use rights in anticipation of changing conditions (subject to social and ecological obligations)
Connectivity *Networks and connections across sectors and scales for mobilisation, cooperation and collaboration*	• Integrated and tiered water use licencing. • Monitoring standards for available and accessible data (publicly available, data exchange). • Consultation process. • Requirements for exchange of data, especially for transboundary basins.
Subsidiarity *Implementation of policies and*	• Locally appropriate standards (broad principles based in primary legislation and implementation of principles set out in secondary legislation).

provisions at lowest or most suitable level.	• Administrative requirements for setting basin specific standards. • Implementation of use rights frameworks at lowest appropriate level.

It should be added that data exchange holds great importance in order for many of these mechanisms to be implementable (Hannah et al., 2011), particularly in relation to individual nations or authorities being bound by the need to manage their own water resources in accordance with their entitlement to an equitable share of transboundary waters (encapsulated in UNWC, art.5). Standards of data exchange vary across international agreements and regions; but the Danube Convention provides a good example of how it can work, requiring its states subject to exchange data regarding inflows and outflows at their borders (Danube Convention 1994). The complexity of the social-ecological systems relevant to water management underlines the need for horizontal coordination between sectoral management authorities. Successful coordination of this sort has proven to be difficult almost everywhere (Caponera, 2007). One notable example of an explicit bid to address this issue at the planning level is the Strategic Environmental Assessment Directive (European Parliament, 2001). Over the rather wider UNECE area and at the international level, the 2010 Kiev Protocol to the Espoo Convention reflects similar concerns.

6. Discussion

Presenting the legal mechanisms according to the four guiding principles of *iterativity, flexibility, connectivity* and *subsidiarity* demonstrates clearly specific and actionable governance mechanism available that seek to strike a balance between uncertainty, flexibility of adaptive approaches and predictability within the legal structures that must frame such approaches. Principles tend to be reinforcing, in that iterative methods allow greater flexibility, which in turn can improve the connectivity between different processes and scales. However, not only are there challenges between balancing these different principles, but questions also remain over the level of aptness to different scales of environmental change as well as to some of the underlying conditions that are critical factors for effective water governance.

6.1 Challenges across Principles

Typically, legislators and drafters of the law must tread a fine line between making legislation that is so flexible that it loses its capacity to provide certainty, and making legislative provisions so monolithic that they very quickly become detached from reality. This task is made especially difficult because if legislation is to remain relevant and credible, it must be drafted in such a way as to take account of all eventualities, including those that may not be fully understood, observed or contemplated by scientists or policy makers at the time of preparation. Policy priorities, technological capabilities and economic realities will change over time, but they move on different tracks from legal provision; thus, foundation legislation needs, to varying degrees, to develop and be supported by new law before ultimately being superseded when policy priorities finally become too inconsistent to be facilitated or implemented through

existing laws. In some, ordinarily poorer, countries, this process is not so clear, with policy becoming the main driver behind planning and spending priorities in spite of the lack of an appropriate legal foundation.

We must also accept that while the optimum scale at which waters and watercourses should be managed is at the drainage basin level, political realities inevitably mean that coordination across political boundaries will be necessary to achieve this as riparian, littoral and super-jacent states to an international body of water will not cede wholesale responsibility for such bodies to supra-national institutions. Compromises regarding data generation and exchange procedures may be made; and practice in the more successful transboundary agreements reflects this (e.g. arrangements for the Indus and Danube), although difficulties may be faced in relation to the ownership of hydrological and meteorological data (Allan, 2012). At the national scale, restrictions on data exchange are limited less by sovereignty issues, but by adequate monitoring networks.

The importance of scale for the effectiveness of institutional appropriateness in terms of responsiveness and flexibility is implicit in participatory irrigation management. There are many examples of Water User Associations (WUAs) at the basin scale (particularly in highly irrigated areas), that often aim to delegate responsibility and decision making to the user level for increased efficiency and effectiveness. Although they have been promoted enthusiastically in the past by organisations such as the World Bank and the International Water Management Institute, implementing WUAs has proved awkward in practice due to insufficient institutional capacity, financing, inadequate legal foundations and limited incentives for users to join (Groenfeldt and Svendsen, 2000). Furthermore, even though such bodies may be multi-sectoral, they are often limited to irrigation and forest users. Power should also be delegated as part of this management transfer process (Vermillion and Sagardoy, 1999). More generally, stakeholder involvement in water resource management across sectors, with respect to planning rather than operationally, is an important aspect of the Water Framework Directive, though again with varying degrees of success (Bourblanc et al., 2012). While the Pangani River Basin WUA in Tanzania is an example of decentralised negotiations on water allocations at river basin scale (Cook et al., 2011) it is in fact not that well supported by the actual law (see Section 4).

6.2 Critical Factors

While Section 5 demonstrates different mechanisms available to policy makers and legislators to develop more adaptive water law and policy, there are of course significant challenges in potential gaps between legislation and institutional capacity, and the ability to implement and enforce the law. The comparison across these legislative frameworks in highly contrasting contexts serves to highlight some key critical factors that law makers must take into account when in the process of reviewing or drafting law in relation to water and climate change adaptation. A major point to make about the adaptive capacity of law is that governance frameworks for the management of water resources are not all made the same. It is true that some environments have

not been adequately protected by the law, but it is also fair to say that some legal systems have made better efforts at trying to address sustainable development than others.

The capacity to effect such changes (i.e. make resource management and long term planning effective) is dependent on a number of key factors, most notably the availability of data. Combinations of public and private use rights frameworks, such as those in existence in Spain, can cause difficulties in this respect because accurate data regarding patterns of use may be incomplete if a sector of users is not contributing data. This is equally true where the consolidation of national or basin water use cadastres is dislocated as a result of incompatible data formats, as is the case in Chile (Hill, 2013) . In some jurisdictions, long term data sets are available with respect to precipitation, river flow, groundwater level and water use patterns; and these are used to determine short term apportionments that take account of inter-annual variability (e.g.in the USA) but even where this is true, non-stationarity may impinge on the accuracy of water availability projections that are based on historical data (Hill and Engle, 2013).

In the examples of best practice outlined above, geographical subsidiarity is evident insofar as decisions are made at an appropriately local scale. Legal or temporal subsidiarity is also apparent, in terms of the process of tying the choice of legal instrument to the importance of the principle being addressed, the likelihood of amendments being needed in the short to medium term and the practical challenges of facilitating those amendments. In the Scottish context, for example, the WFD was transposed in its entirety through primary legislation, while the required regimes for managing abstraction and diffuse pollution, among other parameters, were established through a suite of secondary legislation specifically provided for in the original law (WEWS, 2003).

This approach to legal subsidiarity has not been applied in all jurisdictions. In codified systems (where water use rights frameworks have been consolidated in a code or fundamental law), such as in South Africa and Chile, significant effort has been put into designing an all-encompassing water resource management regime, with very little subsequent modification or scope for elaboration through executive regulation (secondary legislation). In cases where primary legislation requires elaboration through subsequent enactment of more detailed regulations, there is a danger, particularly in less developed jurisdictions, that the former may be negated by torpid development of the latter (whether by design or not). This is especially risky when the secondary legislation is optional rather than mandatory, as in the case of the Tanzanian Water Resources Management Act (2009), which allows the Minister to make regulations for the classification of water resources (s.32[1]). If these regulations are not made, the critical concept of reserves for environmental and human needs will be fatally undermined. To some extent, ensuring the momentum for developing crucial secondary legislation may be dependent on the quality of the relevant policy framework. Where no clear deadlines or reporting mechanisms are set in the policy, as is the case in the

otherwise very comprehensive Bangladeshi Coastal Zone Policy (2005), the possibilities for leverage from the legislature is very much reduced.

6.3 Comparing Best-Practice Examples to the Scientific Evidence Base

One of the major challenges in adaptation to climate change is that the rate, magnitude and scale of change are likely to be beyond past coping capacities (as presented in Section 4.1). Thus, adaptive actions need to be able to respond to potentially increasing levels of change and uncertainty. To address this, in Table 3, we assess whether the approaches presented above are apt in terms of the level of change and uncertainty climate change implies, presenting where current example of best practice may (or still may not) be adequate.

Table 3: Challenges and proposed solution to science-law mismatches: Aptness and remaining challenges of the approaches presented in Table 2, in relation to the shift in conditions presented in Section 4.1.

Governance Mechanisms	**Relation of Approach to each Category of Uncertainty**		
	Stationarity with Predictable Uncertainty	**Broader Range of Uncertainty with Reduced Predictability**	**Irreversibility / Regime Shifts**
Review Periods	Vital for the assessment of outcomes of current policies and plans on social and ecological components of the system.	Vital for the inclusion of new climate observation data into the assessment of current approaches and frameworks.	Vital to incorporate climate scenarios into the review process.
Varied rights: subject to ecological and social parameters	Essential for equitably matching demand to supply in short term.	Regulators can vary use rights in advance of expected changes to overcome the current focus on direct and static sources of drivers of change in current legislation.	Likely to become useful (even if use rights are not or cannot be time limited) in terms of managing larger shifts in timing or volume of availability. Monitoring and data exchange are vital.
Permit systems: time limited licencing	Less important than variability of rights in short term.	Time-limited permits not subject to variability or review will be less effective at incorporating uncertainty.	Maximum duration of the permit (25, 40 years) will influence the usefulness of this mechanism. Variability of permit conditions is required as well for maximum effectiveness.
Use entitlements as share of overall resource	Allows for annual allocation based on expected resource availability (based on existing datasets).	A long term planning framework for entitlements can address and incorporate the situation in 50 years by integrating climate projections for review and revision.	Likely to become useful for managing larger shifts in timing and/ or volume of availability if it is possible to reduce the proportion of the resource that is available for use. Variability and seasonal changes must be addressed.
Water rights trading	Useful for dealing with challenges of distributing rights in areas or times of limited availability. Therefore, this is more relevant to availability than variability.	Possibly not as useful, as speculation (where possible) may skew markets. It is also less useful in terms of prioritising different uses under increasing variability.	Will not address this, unless resource available for trading can be changed over time to take account of projected impacts, projected demand and projected availability.
Administrative	Basin management needed, with	Use cadastres at multiple	Stronger requirements

requirements	appropriate user involvement. Use cadastres at multiple scales must be coordinated.	scales must be coordinated to bolster data needs, reinforce compliance and integrate emerging science.	would be needed for the integration of emerging science and data on impact scenarios.
Qualitative and quantitative standards	Standards for basin specific ecosystem capacity. Combined approach to pollution control (emission limit valuess, water quality standards) is needed to guide short-term permit variability requirements. Abstraction controls necessary for controlling demand.	Variability critical, but in context of combined approach.	Standards must be both reactively variable and capable of being determined in light of new environmental conditions.
Locally appropriate standards: secondary legislation	Appropriate for guiding short-term use right variability.	Secondary legislation adapted to basin/local needs may be appropriate but not imperative.	Primary legislation probably more relevant as fundamental management and governance framework is more likely to address relevant responses.
Monitoring standards for available and accessible data	Requirements for network investment, public availability and data exchange are vital.	[As for administrative requirements (above)	Fundamental to the integration of climate scenarios and data.
Coordination between sectoral management authorities	Essential for ensuring relevant management concerns are reflected in demand management.	Essential for inter-sectoral planning under shifting water availability patterns.	Where regime shifts are projected, inter-sectoral coordination will be crucial to effective adaptation and to implementation of mitigating measures.
Consultation process	Appropriate for ensuring users are aware of equitably-applied variation.	If trust is established, buy-in for infrastructural requirements, demand and supply management measures etc. will be more easily implemented.	Consultation and trust essential for preparing for future scenarios that may not be perceived to be imminent.

Table 3 underlines the fundamental importance that review periods (for rights and standards) and varied rights play in effective governance of water resources under both current and future conditions, underscoring previous comments on how property rights are not immutable. Other mechanisms, such as water rights trading, are not seen as helpful as uncertainty increases. It further underlines the point that for many of these mechanisms to be effective under irreversible changes or post-tipping points, effective monitoring and data provision is paramount. Given the importance of this challenge, future work in both theory and practice should prioritise the investigation and remediation of challenges relating to a lack of knowledge and data on hydro-climatic, other environmental criteria and usage particularly in nations that are most at risk with the least data infrastructure. The ongoing work on climate services, WMO standards and data sharing at international as well as national levels, particularly in developing countries, is a vital starting point (Hannah et al, 2011). Furthermore, academic research could further enhance the understanding of juxtapositions between the availability and applicability of data and climate change information and challenges of decision making under uncertainty.

Finally, the last column of Table 3 presents the many challenges that climate change induced tipping points and more irreversible changes imply for currently effective

governance mechanisms. One question for further investigation is how governance regimes at different levels can manage the challenge of global feedbacks (Biermann, 2012). For example, given local actors limited ability to influence global processes (both climatic and political), a shift of burden to higher levels of governance (Hill and Engle, 2013) may be implied that legislators and local managers will need to navigate.

7. Conclusions

This study has brought together resilience, legal and bio-physical perspectives on climate change impacts on water resources to identify a set of actionable mechanisms that could improve the resilience of water policy, law and regulation to different scales of change. While the body of evidence presented is by no means exhaustive, the translation of principles to practical applications should further enable practioner understanding of how to design policy and law for uncertainty. The mechanisms in Table 2 and the testing framework presented in Table 3 aims to provide guidance on the kinds of mechanisms currently available for the operationalisation of some of the conceptual challenges and principles identified in the adaptive governance and resilience based literature.

The broad based empirical evidence, representative of different kinds of water governance regime, demonstrate how some water laws partially succeed or fail in accommodating resilience based concepts, or enhance of decrease resilience to climate change. These examples show that there is already evidence of how these general design principles (iterativity, flexibility, connectivity and subsidiarity) are operationalised in legislative frameworks, demonstrating ways to alleviate the tensions on which previous research has focussed. The provisions and legal frameworks discussed potentially serve as templates for the shaping and drafting of climate and adaptive water legislation that can balance these issues of flexibility, iterativity with procedural certainty, as well as ensure integration across governance scales through connectivity and subsidiarity. However, certain prerequisites have significant importance for effective implementation of most of these legislative provisions, most notably monitoring and data sharing, financial and technical capacity. Furthermore, keen attention is required to the appropriate scale for different governance mechanisms and legal or temporal subsidiarity to ensure that secondary legislation, amendments and critical concepts are implementable and enforceable at the requisite time and level.

This study has taken a more applied approach to what governance frameworks or mechanisms can actually and concretely do, and what is feasible for decision makers and policy makers to achieve within the different settings they operate. We have sought to move beyond broad guidelines and principles, to provide practicable guidance on how to integrate uncertainty and greater flexibility and adaptability into legal frameworks. In this way, we aim to have contributed to improving the understanding of a core issue in the adaptive governance and management discourse, which so far has

not been adequately addressed in a manner suitable to the practitioner community. We hope that this article enables policy makers and legal drafters to translate the resilience based academic terminology and adaptive governance and management principles into clear instructions for incorporating uncertainty into legislation and policy design.

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