Chapter 22
Characterizing Adaptive Capacity in Water Governance Arrangements in the Context of Extreme Events

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Abstract Climate change impacts on precipitation patterns, glacial retreat and associated changes in runoff regimes are observed from the Alps to the Andes. In order to manage future uncertainty as climate impacts on water resources further unfold, it is vital to better understand adaptive capacity and how it may be developed. Governance is an issue at the heart of the water discourse, with effective water governance seen as essential to building adaptive capacity in communities to manage future climatic uncertainty and stress. Governance and institutional components are more generally seen as key determinants of adaptive capacity, yet there has been relatively little empirical verification of indicators at the local and regional levels, as well as in the water sector. This study aims to contribute to the literature on adaptive capacity in the water sector, through the empirical and analytical development of more robust indicators of adaptive capacity relating to governance and institutions. The paper discusses how extremes can be an effective illustration of one type of climate uncertainty, in which to explore and assess the plasticity and adaptive capacity of the water governance system. Research is based on literature review, stakeholder interviews and statistical analysis of climatic extremes.

Keywords Adaptive capacity · Climate change · Water governance · Extreme events · Switzerland

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Introduction

For most people around the world, climate change will be experienced through changes in local hydrological patterns (Parry et al. 2007). Moreover, mountainous areas, commonly considered "water towers" of the world, are at the forefront of warming patterns. Climate impacts on glacier retreat, precipitation patterns (seasonality and snow line) and associated changes in runoff regimes are already observed from the Alps to the Andes, and model projections suggest a continuation if not heightening of current trends (IPCC 2007b). Climate change is projected to affect the function and operation of existing water infrastructure and institutions, but it is recognized that current frameworks may not be robust enough to cope (Bates 2008). Effective adaptation and building adaptive capacity, therefore, is seen as crucial to managing water resources under the future uncertainty of changing climatic conditions.

Water, Climate Change and Adaptation

In his seminal book *On the Origin of Species*, Darwin famously noted: "It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change". This observation perfectly elucidates how humans have always had to adapt to change, including climatic and meteorological variation. So what is different now? Why do we worry so much about society's ability to adapt to future variation in the 21st century? The answer to this can be found by looking at the speed of current climatic change, and the complex geopolitical-environmental context within which it is and will take place. As the different planetary systems move towards threshold or boundary conditions, which lie outside society's range of experience, resilience and the ability to adapt decline (Rockström et al. 2009). Current rates and type of change have meant that a more concerted effort must be placed on creating an enabling environment for adaptive capacity to accelerating rates of change in today's more complex and interconnected world.

The retreat of mountain glaciers is one of the clear indications that certain sub-systems of the earth are moving out of their relatively stable holocene state, and into an age becoming known as the anthropocene (Rockström et al. 2009). The movement towards such boundary or threshold situations have led some within the water sector to suggest that the concept of "stationarity" is dead, and that the lessons of the past can no longer guide how we manage our future (Milly et al. 2008). This implies that a shift in how we plan and manage water resources is needed, which respects non-stationary conditions and increased levels of uncertainty. To meet these challenges, the water resources and research community have in recent years focused more heavily on better understanding adaptive processes.

Some of the key concepts in this growing body of literature are vulnerability, adaptive capacity and resilience. *Vulnerability* is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes (Parry et al. 2007). Vulnerability is comprised of a number of components including exposure to impacts, sensitivity and the capacity to adapt (Adger and Vincent 2005). *Adaptive capacity* is the capacity of actors, individuals and groups to respond to, create and shape variability and change in the state of the system (Chapan et al. 2009). It can be characterized by preconditions necessary to enable adaptation, including social and physical elements, and the ability to mobilize these elements (Nelson et al. 2007). For the purpose of this article, *resilience* is the ability of a socioecological system to absorb disturbances while retaining the same fundamental structure, function and identity, including the capacity to adapt to stress and change, through either recovery or reorganization in a new context (Parry et al. 2007; Chapan et al. 2009).

There is also wide recognition of the importance of institutions and governance mechanisms for building adaptive capacity and resilience (Nelson et al. 2007; Brooks et al. 2005; UNECE 2009), the role that public policy plays in fostering adaptive capacity at local and regional levels (IISD 2006), as well as the need for flexible approaches (UNECE 2009). In the preceding decade, adaptive capacity has become a more mainstream concept. As the IPCC (2007a) stated, climate change implies a speed and magnitude of change, which poses risks that are beyond the human experience and potentially the boundaries of coping ranges. Yohe and Tol (2002) suggest that determinants of adaptive capacity have a key role in defining the potential the boundaries of coping ranges. Determinants of adaptive capacity have been defined as including a variety of system-, sector-, and location-specific characteristics (IPCC 2001):

- the range of available technological options for adaptation,
- the availability of resources and their distribution across the population,
- the structure of critical institutions, the derivative allocation of decision-making authority, and the decision criteria that would be employed,
- the stock of human capital including education and personal security,
- the stock of social capital including the definition of property rights,
- the system's access to risk spreading processes,
- the ability of decision-makers to manage information, the processes by which these decision-makers determine which information is credible, and the credibility of the decision-makers themselves, and
- the public's perceived attribution of the source of stress and the significance of exposure to its local manifestations.

Adaptive Capacity

Building adaptive capacity, by cultivating or contributing to the presence of the above factors in communities, improves the ability of systems to be become resilient to surprises and longer-term changes (IISD 2006). The determinants of adaptive capacity lay the foundations for a number of different features and principles, which are seen as useful indications of a system's adaptive capacity, which will be discussed later in this paper. A number of theoretical discourses have developed, such as adaptive management, adaptive co-management and adaptive governance, in the quest for resilience in the face of uncertainty and climate change. Many of these theories focus heavily on the idea of "learning by judicious doing" (Holling 1978), which represents a departure from the more traditional approach of rigid and irreversible planning and anticipatory management to a concept of policy experimentation.

Adaptive governance is seen to meet the call for dealing with increased uncertainty and change, arising from the "growing number of failures among current approaches and increasing vulnerability of social-ecological systems" (Olssen et al. 2006, p. 1). Within the specific context of river basins, Pahl-Wostl et al. (2007) noted that more attention needs to be devoted to understanding and managing the transition from current management regimes to more adaptive regimes that "take into account environmental, technological, economic, institutional and cultural characteristics of the basin" (p. 49). Similarly to the adaptive management field, the concepts of learning by doing, social learning and scenario planning have become popular as a means of operationalizing the need for flexibility and better integration of social and ecological factors. These approaches are seen as a response to the challenge of "creating governance structures that are flexible and robust in the face of uncertainties and inevitable surprises" (TwinGo 2010, p. 3).

This paper presents the theoretical and empirical development of research presented at Climate 2009 on vulnerabilities in the water governance arrangement of the Rhone Basin in the canton of Valais, Switzerland. It builds on this previous research, discussing the challenges in developing indicators to better characterize and assess adaptive capacity. It presents a synthesis of the current state of indicators on adaptive capacity, and discusses the challenges arising from the mostly normative characterization of adaptive capacity. It uses results from earlier research combined with literature review to identify and theoretically develop characteristics of adaptive capacity. It then sets out a means to further test and develop these using the empirical setting of past extreme events and presents some initial results from preliminary stakeholder interviews. It suggests that the use of both qualitative and quantitative research techniques could lead to a more integrated understanding of physical and institutional attributes of the system.

Assessing Adaptive Capacity

The assessment of adaptive capacity is inextricably linked with that of adaptation. While the assessment of adaptation actions tend to be addressed within a framework of whether the outcome of such actions are equitable, effective and legitimate, there are also significant questions about not *how we adapt*, but rather *whether we can adapt*. The concept of adaptive capacity is used as a point of departure to determine measurable indicators that "could sustain comparable analyses of the relative vulnerabilities of different systems located across the globe and subject to a diverse set of stresses that lie beyond their control" (Yohe and Tol 2002, p. 25).

Such indices can be either qualitatively or quantitatively based, generated through formulaic or discursive data, but are critical for the management of risk in relation to climate change impacts. Engle and Lemos (2010, p. 3) note that "decision makers are interested in identifying and nurturing specific system characteristics that will increase adaptive capacity and resilience". The identification of determinants and indicators of adaptive capacity provide a broad suite of characteristics, among which governance and institutional processes are deemed particularly important for the development of adaptive capacity, reduction of vulnerability and prevention of overt and lasting damage from climate change (Nelson et al. 2007; Brooks et al. 2005).

A number of studies have highlighted that there are significant challenges in assessing adaptive capacity (Engle and Lemos 2010; Smit et al. 2000) since "adaptive capacity is latent in nature (…) it can only be actually measured after it has been realized or mobilized" (Engle and Lemos 2010, p. 5). However, the study of adaptation to climatic events can to a certain degree overcome the pre-impact intangibility of adaptive capacity. Smit et al. (2000) show that by studying system responses to past climate variability (which tends to be experienced through the nature and frequencies of extremes), it is possible to identify attributes of the system which were key to either successful or failed responses. Such studies of adaptation to extreme events have highlighted the importance of institutions and governance mechanisms for the capacity or inability to deal with change (Brooks et al. 2005; Engle and Lemos 2010).

Background

Case Areas

The two case studies chosen from the ACQWA case regions are the Rhone Basin in the canton of Valais, Switzerland and the Aconcagua Basin in Valparaiso, Chile. This paper will focus on the Swiss case area, in which the water governance framework is characterized by the "principle of subsidiarity", which defines the

Fig. 1 View of Valais, depicting the high peaks and low, highly cultivated valley floor. Available at http://valais.ialpes.com/gastronomie/gastronomie-valais.htm

decentralized implementation of public policy and law at the cantonal and municipal levels. The upper Rhone flows through the valley floor of the Valais. The area is characterized by an inner alpine arid climate, with large discrepancies in precipitation between higher and lower elevations. While water conflicts have been rare, periods of increased competition have been experienced more recently. The region has traditionally needed to cope with a range of events from flooding to low precipitation. Climate change impacts in the Swiss alpine areas will lead to enhanced glacial retreat, melting of permafrost, as well as the changes in vegetation and precipitation (Figs. 1, 2).

Higher winter temperatures and a more marked increase in summer temperatures will be noted. Precipitation will also be higher and more intense in winter, but much reduced in summer months (Häberli and Beniston 1998; Fig. 1). The largest source of vulnerability from climate change is likely to come from changes in the intensity or frequency of extreme events, such as heat waves (winter and summer), heavy precipitation events and drought (Beniston et al. 2007). Increased glacial melt also is leading to an increase in flood risks and other natural hazard events (OcCC 2008) (Fig. 3).

Increased flooding and extreme precipitation events are compounded by an increase in risk exposure due to infrastructure/housing development in vulnerable areas which are currently seen as "safe" due to technical interventions. Temperature increases at alpine elevations raise demand for water uses such as artificial snow making and summer cooling/drinking water leading to complex management shifts, compounded by changes in seasonality. There have already been examples where a lack of planning for drinking-water supply has led to sectoral issues between hydropower use, tourism use and drinking-water supply (Reynard 2000), as well as tensions between the hydropower and agricultural sector which arose in the 2003 summer heat wave.

The impacts of climate change may also compound the reduction in ecological status of many surface waters in Switzerland. Of 65,300 km of surface waters in Switzerland, 10,600 km have been considerably altered through technical projects, thereby impairing their ecological functions (FOEN 2009). Hydropeaking

Fig. 2 Districts of Canton Valais. Artist: Tschubby, 16 August 2004

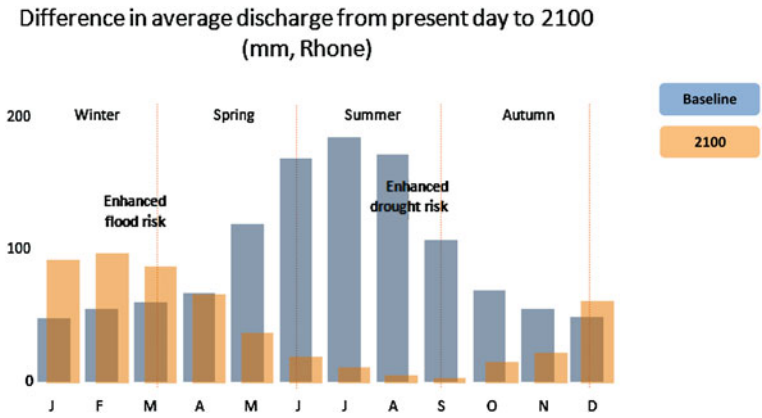

Fig. 3 Adapted from Beniston et al. (2007, p. 228). It represents the difference in seasonal distribution of runoff for the river Rhone between baseline values (1961–1990) and projected values for A2 SRES scenario (800 ppm) by 2,100. The bars aligned the *left* represent baseline runoff, showing typical seasonal flows (high runoff in summer, low in winter) for an alpine regime. The bars aligned to the *right* show the 2,100 projection, with increased runoff during early spring (increasing flood risk) and decreased runoff in mid- to late summer (increasing drought risk)

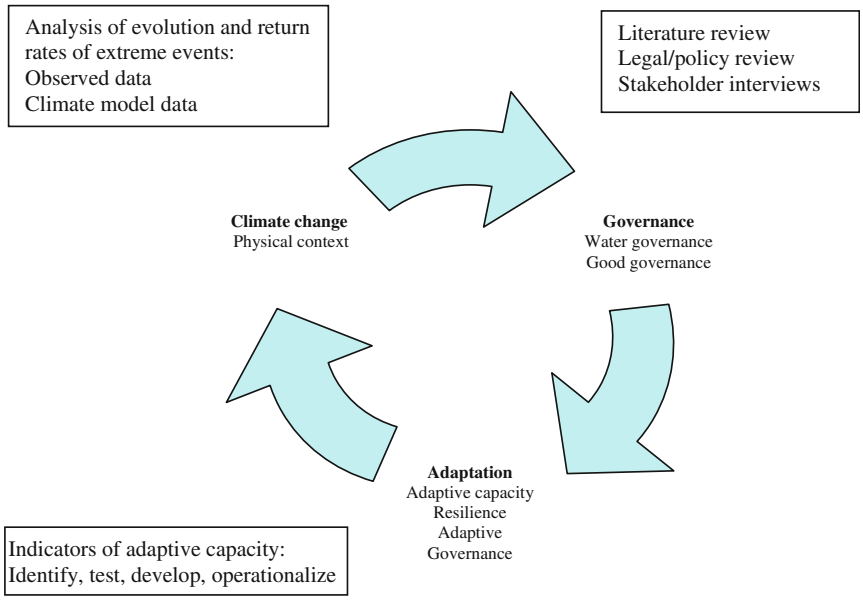

Fig. 4 Conceptual framework with associated methodological steps

(artificial high and low flow phases) also impacts rivers, in that they regularly dry up from over extraction of water, with damaging impacts on aquatic ecosystems.

Methods

An initial governance assessment, based on the Striver/Brahmatwin methodology (Allan 2008) was undertaken in order to understand the current vulnerabilities in the water governance system (Hill 2010). The Striver assessment drew on a number of good governance criteria, including transparency, accountability and participation, combining it with a set of IWRM-related sections. However, given the future uncertainty due to global change, deeper analysis of the system's adaptive capacity sought to contribute to the development of the governance assessment. To this end, extensive literature analysis identified key components of adaptive capacity to develop a further set of indicator questions for measuring adaptive capacity. Stakeholder interviews at the federal level and cantonal level in the Valais were used to critically appraise some of the normative assumptions within the governance and institutional determinants of adaptive capacity (Fig. 4).

Additionally, in order to ground the development of these indicators in empirical evidence, past examples of extreme climatic events will be used to explore particular problems experienced under climate extremes. The case studies of extreme events allow for deeper investigation into the potential performance of the governance system under climate change impacts. These case events in each

case area will serve as reference points of climate variability and as useful indications for the impact of extremes in a future climate. Return period analysis was used to understand the current development of such events (trend analysis) and to project the likelihood of such events happening under climate change scenarios (return period analysis). Further stakeholder interviews in each case area, at the local and cantonal level, are then used to develop and refine the indicators, as well as provide important insights into the adaptive capacity of the water governance systems.

Review of Indicators of Adaptive Capacity

Within the water sector, there is a general call for all new water management measures to be climate-resilient. Adaptation strategies therefore aim at reducing vulnerability, including the possibility of increasing adaptive capacity (UNECE 2009). Water managers and scientists are progressively looking to integrated water resources management (IWRM) and adaptive management to help mitigate not only governance failures of the past, but also uncertainty in the future (Ingram 2011). IWRM places more emphasis on collaborative governance and the recognition of the multiple values of water, and is seen as one means to increasing capacity of water management in the face of climate change. Institutional capacity is also seen as a critical requirement in effective adaptation, particularly in the clarity of roles and responsibility of individual authorities, especially in extreme event situations (UNECE 2009).

In the literature on good governance, and therefore in the governance assessment itself, adaptive capacity to climate change tends to be assumed if indicators of good governance are adequately met. Results from the governance assessment in the Swiss case area showed that despite the water governance system performing well under the three initial indicators (accountability, transparency, participation), serious concerns were raised about its ability to cope and adjust to a changing climate and rising competition on water use, mainly through the lack of integration across different geographies and users (Hill 2010). Issues also arose in interviews which suggested that a correlation between "participation and decentralization" and greater adaptive capacity should not be taken as a normative assumption. The following section discusses why these presumptions should not be assumed and suggests how other indicators could be further developed and tested to determine adaptive capacity.

Tools and concepts used to measure the validity of outcomes of adaptive actions can also be employed to assess underlying states beneficial to the development of adaptive capacity. A number of determinants of adaptive capacity have been identified within the climate change impacts, adaptation and vulnerability literature (CCIAV). To recap, common factors considered determinants can be categorized into the following groups: economic resources, technology, information and skills, infrastructure, institutions, equity, social capital, and collective action (Engle and Lemos 2010; Eakin and Lemos 2006; Yohe and Tol 2002;

IPCC 2001). However, empirical verification of the merit of these norms for building adaptive capacity is sparse, particularly within the water sector (Engle and Lemos 2010; Wilbanks and Kates 1999).

Accountability, Participation, Transparency

The four indicators of the STRIVER assessment—accountability, participation, transparency and IWRM—were not specifically designed to measure adaptive capacity, but were rather shaped in the context of good governance for IWRM. However, these indicators also play different roles in other adaptive capacity assessments (Hurlbert 2008; Engle and Lemos 2010; Iza and Stein 2009). Accountability, participation and transparency are often considered key principles in adaptive capacity. A recent IUCN report (Iza and Stein 2009) refers to different process principles in the discussion on reforming water governance, which are requisite to provide an enabling environment, including transparency, accountability and participation. Their definition of participation broadens out from more than just consultation in decision-making to involvement in multi-stakeholder platforms and decision-making at the lowest appropriate level. It is considered these elements of participation could effectively raise levels of awareness, co-management and citizen initiatives, all components deemed necessary for fostering effective water governance capacity as well as sources of resilience in social-ecological systems.

IWRM and Integration

IWRM is currently held up as the ideal framework for managing water in an integrated and sustainable way that would enhance the system's resilience to cope with the impacts of climate change on water resources. However, despite the concept's use in addressing the need for water governance processes to effectively and equitably manage the fair distribution and protection of the resource, it has weaknesses in terms of complexity, uncertainty and adaptive capacity (Timmerman et al. 2008). Timmerman et al. suggest that in addition to recognizing multiple uses of water, multiple sources of knowledge and information should also be integrated into management systems.

Olsson et al. (2006) explore the different features that contribute to the resilience of social-ecological systems in the face of change (in the context of adaptive co-management). Their criteria do not follow the neat normative categories of many of the other studies into adaptive capacity, but provide some useful insights into governance-related criteria which can provide an enabling environment for enhanced resilience to environmental shocks and stresses. They suggest that an "enabling legislation that creates social space for ecosystem management" is

requisite for the building of resilience. As vague as this may be, it deems that in order for resilience to be fostered, the institution of law should ensure that ecosystems and the environment are factored in as a relevant stakeholder. Not only should sectoral actors be integrated into legislation relating to resources (water in this case) but institutions also need to take account of ecosystem needs. This concept finds resonance with the element of integration and recognition for the non-economic uses of water within an IWRM context.

Leadership, Trust, Commitment

Olsson et al. (2006) use the criteria of "vision, leadership, and trust", which share some normative properties with accountability, in terms that an unaccountable system will not generate trust amongst its citizens. However, there is no reason to equate vision or leadership with the same norm, but both could be seen as requirements for the necessary political will requisite to foster proactive responses to climate change and develop relations across different networks and levels of decision making. Folke et al. (2005) also suggest that vision, trust and innovative leadership can provide key functions for adaptive governance, e.g., "building trust, making sense, managing conflict, linking actors, initiating partnerships, compiling and generating knowledge, mobilizing broad support for change".

The importance of these elements of leadership in building collaboration and resolving conflicts is underlined by its role as a key component in bridging interests and stakeholders and to a certain extent driving realization of other principles of adaptive governance. Leadership can be seen as an abstract concept, which can be highly subjective to personal opinion. Additionally, strong leadership may not always have a positive correlation with principles of adaptive governance, but it may be inferred that meeting the other principles of adaptive governance may not be as possible without the presence of leadership. Linkages may also exist with accountability, resources, networks, transparency and participation. Engle and Lemos (2010) also discuss the indicator "commitment", which refers to the belief held by the different stakeholders that the institutional and governance structures in place are adequate for managing the resource as effectively and efficiently as possible.

Experience

Engle and Lemos (2010) note that more experience would correlate with a greater ability to deal with everyday events, as well as extremes, in an effective and efficient way. While experience can broadly be deemed as relevant, just as with the concept of leadership, precise measurement of this principle is very abstract. However, although an actor may have many years of experience, preconditioned

ideals or values may subject his/her decisions to preconceived notions, which may or may not still be relevant for changing conditions. UNECE (2009) highlight the importance not just of career experience, but also fostering experience through training and simulation exercises on a regular basis.

Resources

Olsson et al. (2006) propose "funds for responding to environmental change and for remedial action; capacity for monitoring and responding to environmental feedback" as indicators which both relate to the importance of human and financial resources for ensuring effective capacity for monitoring systems, enforcing laws and responding to extremes or feedbacks. The importance of information- and knowledge-sharing, not just in itself, but across different levels of stakeholders and decision-makers is touched upon through criteria 5 and 6 ("information flow through social networks; combination of various sources of information and knowledge"). These criteria are also relevant for the creation of the appropriate level of public perception (Yohe and Tol 2002) for adaptation through sense-making and collaborative learning (Olsson et al. 2006). Engle and Lemos (2010) also comment that levels of financial and human capital are critical for overall success of an organization or governance structure. Yet, while more resources (financial and human) may increase the capacity of the system, it is how these resources are applied and organized that may be more important. Less could mean more. There may also be linkages with experience, networks, accountability, transparency and decentralization.

Networks and Connectivity

Folke et al. (2005) explore the social elements of adaptive governance, which can enable adaptive ecosystem based management in the context of abrupt change. "Connectivity across Networks" refers to connectivity across individuals, organizations, agencies and institutions through bridging organizations. Networks capture the various institutional levels and relationships involved with river basin management. Folke et al. (2005) also suggest that adaptive co-management requires more flexible social networks, which may be more innovative and responsive than bureaucracies in times of rapid change. It is assumed that the greater the networking and connectivity between groups and stakeholders involved in the management processes, the greater the adaptive capacity (Engle and Lemos 2010). Just as in the critique of participation, connectivity alone may not imply a willingness to cooperate, which is requisite for systems to be adaptive (UNECE 2009).

Predictability—Flexibility

Flexibility is to be taken as the antithesis of irreversibility. This indicator is repeated across a number of the studies on adaptive capacity. The UNECE comments that "the capacity to adapt requires flexibility. As a result, measures that are highly inflexible or where reversibility is difficult should be avoided" (UNECE 2009, p. 78). In institutional terms, it refers to an ability to bend, but not break, and to learn iteratively, incorporating lessons learnt through experience efficiently and effectively (Engle and Lemos 2010). This concept of *iterative adaptive governance/learning by doing* is a key element of adaptive management and governance (Olsson et al. 2004; Pahl-Wostl et al. 2007). The assumption is that the greater the flexibility of rules (legislation, institutions), the greater the adaptive capacity (Engle and Lemos 2010). However, there is a struggle here between flexibility for adaptive management, and the need for certainty (Iza and Stein 2009; Tarlock 2009) or predictability (Hurlbert 2008) within the law. Predictability suggests that all laws and regulations should be applied fairly and consistently. The assumption is that consistency in application of the law will enhance adaptive capacity. The IUCN (Iza and Stein 2009) use a similar concept in the process principle of "certainty", which rests upon the rule of law in terms of both predictability and enforceability. This would of course be dependent upon laws also reflecting principles of ecological integrity, equitable access for all and linkages between land and water resources. Otherwise, rigidity in the application of "bad" laws and policies would diminish adaptive capacity.

Knowledge and Information

The UNECE (2009) cite the importance of supporting training and response systems with climate and hydrological information systems, which are "capable of delivering early warnings in a timely and efficient manner" (UNECE 2009, p. 42). Folke et al. (2005) relate the idea of knowledge with the creation of an iterative learning environment. There are therefore important links with *flexibility* through the process of learning by doing. The goal here relates to an improved understanding of the dynamics of the whole system so that an understanding is established for how to manage periods of rapid change. The interpretation of knowledge is also highly linked with how to effectively deploy scientific information across different networks or levels of decision-making for the management of resource issues in the context of change. Engle and Lemos (2010) also refer to the linkage of using scientific knowledge and information with the building of adaptive capacity, but add to the concept the importance of equality of decision-making and knowledge use (in terms of power distribution among stakeholders and access to technical knowledge). Nelson et al. (2007)

also suggests that the ability to maintain a response capacity is predicated in part on the capacity for learning.

Decentralisation

Decentralization and subsidiarity (Hurlbert 2008) refers to the delegation of responsibility and authority of water management to the lowest feasible level. Devolved decision-making means that a system would be "presumably, better able to recognize and respond to unforeseen circumstances" (IISD 2006, p. 119). There a theoretical link here to the IWRM component "Basin/Watershed Approach", as well as to Olssen et al. (2004) concept of enabling legislation that creates social space for ecosystem management. Yet, while a system may be highly devolved, this does not imply that there are ecological based units of decision-making.

Discussion

This list of indictors captures the development in the analytical field of adaptation and vulnerability in the preceding decade. However, it is equally recognized that there has been fairly minimal empirical verification of the correlation between different principles and indicators of adaptive capacity, particularly at local and regional scales, and more so within the water sector (Engle and Lemos 2010; Wilbanks and Kates 1999). There are a number of analytical challenges relating to the different principles and indicators of adaptive capacity listed above. The next section discusses these and proposes how further theoretical and empirical research could contribute to improving our understanding of which elements in which circumstances may create an enabling environment for adaptive capacity.

Normative Principles Versus Open Indicators

Much of the discussion around governance issues in adaptation and adaptive capacity has a strong normative edge. Normative principles such as accountability and participation tend to denote a stronger bias towards the researcher's analytical framework. More open indicators such as knowledge and levels of decision-making are less prescriptive and therefore predisposed to be more iteratively developed through the research process, both the theoretical and empirical exploration. While this distinction should be recognized, and normative bias to the analytical framework should be avoided where possible, it should not be seen as a major impediment to the development of more robust indicators. However, for the sake of the iterative development of indicators within this research, more prescriptive and normative indicators employed within the STRIVER assessment

have been replaced by more open indicators. Additionally, it is difficult to make a priori judgements on issues to do with levels of financial and human resources, leadership or even experience. Instead, these indicators should be explored in an a posteriori framework, to investigate correlations with adaptive capacity across different scales (sectors, geographies, political levels).

Process Versus Outcome

There is a difference between the process indicators as described in many of the studies, and the more outcome associated determinants in others. Requirements such as "enabling legislation that creates social space for ecosystem management" (Olsson et al. 2004) and "institutional capacity" (UNECE 2009) can be seen as requisite for an enabling environment for adaptive capacity, but also as an outcome of sufficient adaptive capacity. A key issue is therefore how questions relating to enabling legislation and institutional capacity could be integrated into more open indicators. Or, are such concepts in fact outcomes of indicators such as "levels of decision-making and networks", and therefore should not be separately tackled within the adaptive capacity assessment per se? More specifically regarding "institutional capacity", one could perhaps infer that if indicators such as transparency, knowledge, networks, resources, decentralization/subsidiarity and experience are met, then institutional capacity should be strengthened, therefore it could be taken as an output.

Similarly, the issue of "process versus outcome" is pertinent to IWRM. While IWRM is not considered an indicator, its component parts could be seen as useful determinants of adaptive capacity. An indicator for "integration" could encapsulate a key element of IWRM. The initial Swiss assessment showed that its prime weakness in the face of future change was the lack of integration across different sectors, levels and geographies, indicating that a lack of these components may decrease adaptive capacity of the system, thereby increasing its vulnerability to external shocks and environmental change. Normative prescriptions could be avoided by not suggesting that an ideal level or type of integration pre-exists, but that different levels and types may enable adaptive capacity in varying sectors or geographies. Additionally, considering that numerous studies (including the Swiss governance assessment) have shown that "a substantial gap exists between promise and practice" (Ingram 2011, p. 2) in IWRM, it would be make more sense to focus on how different types of integration rather than IWRM per se contribute adaptive capacity, than testing normative assumptions based on the criteria of IWRM.

Finally, the concept of environmental integrity or ecological system resilience (Nelson et al. 2007) appears regularly as a key determinant for adaptive capacity in the adaptive management discourse. Since the capacity of aquatic ecosystems to produce many of the goods and services on which societies depend is rapidly declining, the provision of water for nature/nature as a buffer can be seen as a key

determinant of adaptive capacity in a system under stress. If the biological component of the system is already under stress, then adapting to more extreme conditions may be limited. Principles purported within the adaptive governance literature are linked with achieving these outputs, but again the question arises of how to define the relationship between ecological integrity and resilience with adaptive capacity.

Decentralization, Participation and Governance Modes

Preferences concerning the right mix of modes of governance (hierarchy/state, market/private and decentralization/civil society) are rife within the literature on adaptation and vulnerability, despite the recognition by many that what matters is that prescriptions fit contexts (Ingram 2011). The focus on full participation and decentralization in water management as desirable norms is reflected across a broad swath of the literature (Hurlbert 2008; UNECE 2009; World Bank 2002; UNDP 1997; Nelson et al. 2007). However, other studies note the fact that decentralization and participation per se are not a priori requirements for better management and enhanced resilience. Berkes in Nelson et al. (2007, p. 409) suggests that "the balance of evidence shows that neither purely local level management nor purely higher level management works well by itself" (p. 239), and Lemos and Agrawal (2006) highlight the development of emerging hybrid, multilevel and cross-sectoral forms of environmental governance. Hill (2010) suggests that there may be a limit to the level of devolvement, and that it can only be effective when combined with requisite levels of experience and resources as well as a propensity for stakeholders to work across the other levels of decision-making.

Ingram (2011, p. 8) adds that "participation is no panacea for water conflicts". Other studies such as Iza and Stein (2009, p. 8) elaborate that other factors such as coordination across levels, rather than pure participation and decentralization hold significant importance. Results from earlier work (Hill 2010) also support these findings, which suggests the need to look beyond prescriptive norms such as participation and decentralization and subsidiarity, to more exploratory indicators which allow examination of causal relationships between different indicators and adaptive capacity within different sectors as well as governance regimes.

Knowledge and Information

In a number of studies the indicator of transparency is pinpointed as fundamental to good governance and adaptive capacity. However, drawing on studies and publications in the resilience framework and the wider climate dialogue, it might

be worth broadening out from the normative prescription of transparency to a more thorough exploration of the contribution that different forms of knowledge and/or information play in enhancing resilience. By looking at knowledge as well, we therefore refer not just to scientific information and data (hydrological models, climate models, economic statistics, etc.), but can also recognize the potential importance of local and indigenous knowledge. A recent report from Switzerland comments on the need to take account of and integrate traditional knowledge in climate data systems (Lugon 2010).

An awareness of the need for climate services also recently arose out of the 3rd World Climate Change Conference in Geneva (WCC-3 2009), which refers to the provision of climate information (both current climate variability and recent and future climate change) (Lugon 2010). It also calls for better management, communication and understanding of this information so that resource managers and the public alike can actually generate knowledge out of the wealth of data and information available. The HEID report comments that while today, people are likely to be inundated with information, often "the hurdles are not the hard science but the communication" (Lugon 2010, p. 64). It also notes that climate information per se is not enough; to be truly valuable it needs to be integrated with socio-economic and other environmental data. It is therefore important to investigate not just what kind of information decision-makers are getting, but also how they use it, with whom they share it and how relevant it is to the problem they need to resolve.

Empirical Application

Using Extreme Events to Explore Tentative Indicators

Following on from the discussion above, a more refined list of tentative indicators has been proposed, which will be empirically explored through stakeholder interviews in each case region. They are: knowledge; networks; levels of decision-making; integration; predictability/flexibility; experience; resources; leadership (Table 1). The indicators and sub-criteria draw on current understanding and the different indicators in the discipline of adaptive capacity, adaptive governance and adaptive management, as well as the discourse on integrated water resources management. They have been supplemented with understanding based on theoretical exploration and results from the initial governance assessment within the Valais case area.

Previous studies assessing the adaptive capacity of water law to climate change have utilized case studies of water stress events to provide insights into important modifications in the institution of water law which will increase adaptive capacity (Hurlbert 2009). The IPCC (2007a) also recognizes that "empirical knowledge from past experience in dealing with climate-related natural disasters such as droughts and floods (…) as well as longer term trends in mean conditions, can be

Table 1 Level 1 operationalization of tentative indicators to be further explored and developed in interview

Tentative indicators	Sub-criteria
Knowledge	Right to information; communication/public perception; spatial planning; access to scientific/environmental information; exchange of data and information; integration of scientific expertise; quality of scientific information; use of traditional and local knowledge
Networks	Access to participation; selection of non-state actors; level of influence; type of participation; stage in the political process; social networks; professional networks; willingness to cooperate
Levels of decision-making	Ecological based units of decision-making; institutional arrangements
Integration	Geographical integration; sectoral/uses integration; political integration
Flexibility/predictability	Consistency in rule of the law; rigidity of legal provisions; iterative elements of law/institutions
Resources	Financial resources; quantity/quality of human resources; organization of resources; independence/impartiality of experts
Experience	Training and development; years of experience
Leadership	Political commitment; facilitating role; initiation of partnerships; support mobilization; linking of actors; trust amongst stakeholders

particularly helpful in understanding the coping strategies and adaptive capacity" (p. 138). This study therefore is utilizing case studies of past extreme events relevant to the two basins, which can serve as reference points of climate variability and as useful indications for the impact of extremes in a future, warmer climate.

In order to move beyond the characterization of adaptive capacity to be able to assess which specific approaches are associated with higher adaptive capacity, it is necessary to establish some qualification and quantification of the extreme event impacts. Therefore, to contribute to the characterization of adaptive capacity, the impacts and evolution of extremes were analysed at six climate stations in the Valais (Ulrichen, Sion, Visp, Zermatt, Gd. St. Bernhard and Fey). Summer heat waves were characterized by analysing temperature and precipitation data from June–July–August (JJA). Extreme precipitation events were characterized through August–September–October (ASO) precipitation records. Table 2 depicts a general overview of the types of case events used for the assessment of adaptive capacity, and the associated impacts for each event.

Climate model data from the ACQWA project to calculate return periods as per A1B and B2 emissions scenarios. Initial results from the stations at Visp and Zermatt are detailed below (Fig. 5).

Additionally, impacts data will be gathered at the regional and local level on alterations in water allocations as well as in water reserves. This will be done through both interview and physical data. Figure 3 represents projections of the development of enhanced drought and flooding risk in the Rhone basin. The graph suggests that summer months could experience enhanced drought situations through reduced glacial mass and precipitation, while in winter months increased

Table 2 Details of impacts on separate categories of water goods and services per each extreme event

Geomorphological impacts	Impacts on water goods and services Beniston (2005); Beniston et al. (2007)				
	Non-domestic consumption	Energy	Environmental flows	Transport and absorption of wastewaters	Domestic consumption
Summer heat wave Permafrost degradation and reduction in the cohesion of slope material, acceleration of glacier retreat	Heat stress, enhanced evaporation, droughts, soil-moisture depletion, acceleration of glacier retreat (which can also lead to increased river levels)	Changes in hydro-power supply because of seasonal shifts in the filling of dams	Damage to eco-systems through excessive heat and drought. Increased glacial retreat can leads to river level rising	Reduced flow increasing concentration of chemicals in water ways. Increased glacial retreat can leads to river level rising	Drinking water is always prioritized
Extreme precipitation Slope instability events in mountain regions, increased frequency and severity of floods	Sediments deposited in large quantities on agricultural lands, irrigation canals and streams—reductions in agricultural production	Erosion, discharge and sedimentation rates—damage to hydropower infrastructure		Increased flows causing overflow of wastewaters into water ways	

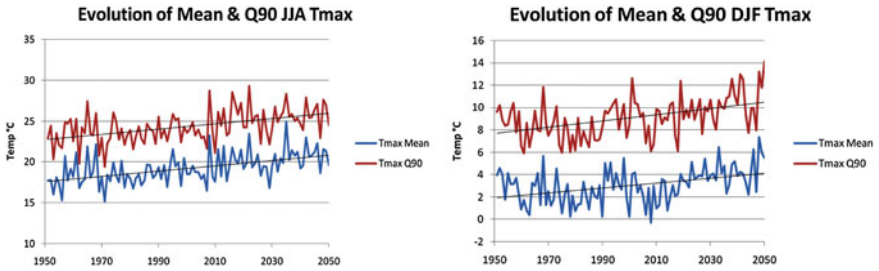

Fig. 5 Evolution of temperatures at Visp according to A1B scenario for summer temperatures (*left*) and winter temperatures (*right*)

intense precipitation periods could not only impact on flood risk, but a wide range of geomorphological processes such as landslides and rock falls.

Stakeholder interviews were conducted at the local and regional level in the Valais, in order to better characterize and assess the mobilization of adaptive capacity in response to the case events. The semi-structured interviews consist of questions relating to the different indicators, lasting 45–90 min with a range of individuals with expertise and experience in water and natural hazards policy and management at the local and cantonal level. Three sub-case areas were identified in the Valais, consisting of six communes that were representative of the different sectoral interests as well as the different microclimates in the Valais. The qualitative data from these interviews serves to provide greater insight into the indicators and will be used to operationalize the criteria of the indicators, as well as assess its mobilization in response to the events. A discussion of preliminary results from interviews in the Swiss case area is found in the following section.

Discussion: Key Issues for Adaptive Capacity

The predominant issue in the Valais canton is flooding. While there has been long-term experience of floods and related hazards, experts interviewed noted that the volume of water has significantly increased since the 1990 s, due to an increase in runoff from glacial melt. This has led to increased damage from floods and associated geological hazards. Interestingly, during the major heat wave in 2003, the Valais experienced increased runoff from glacial melt into the waterways. This served to buffer issues from the lack of precipitation during the event, and actually led to a situation where water levels in the Rhone, its lateral rivers, as well as connected groundwater sources reached high water marks. However, this trend is not projected to last (see Fig. 3). Some experts suggested that they are currently experiencing the peak of contribution from glacial melt, and in the near-term future, a decline will be observed.

Interviewees did point out that there have been increasing numbers of communes which have experience scarcity situations, predominantly in springtime

or during winter months in the ski resorts. This tends to be dependent on a number of factors, such as amount of precipitation during winter, when the snowmelt begins, amount of precipitation falling in spring (e.g., April), which all impacts on how quickly the springs can recharge after winter.

With reference to the indicators, issues were raised with data *integration* across the different politico-administrative levels and disciplinary-sectoral foci. While there is little integration of climate change and ecosystem concerns (beyond a subconscious awareness) into the cantonal and communal offices so far spoken with, there are overriding legal and financial incentives for local actors to take these issues into better account (for more information on the Neuefinanzausgleich, see Hill 2010). Additionally, the Third Rhone Correction (Hill 2010) could be seen as one of the first attempts to better integrate different sectors and ecological and climatic concerns in water management in the Valais.

In some cases, such as Les Bagnes (the municipality which includes the tourist village Verbier), the municipality has had experience of over-demand in peak times (rather than scarcity) and issues of a lack of interconnection between neighbouring villages. Thirty to forty years ago, all the water resources of these villages were separate, so if they had issues of supply during a certain period, they had to deal with this alone. This has been managed by connecting the resources, so that where villages have only one source, they can now be integrated into the network, accessing resources higher up the mountain, or with other villages that have plentiful water. Creating a larger and more connected network of supply has allowed Les Bagnes (and in another case, Crans Montana) to better manage the peak demand during the winter tourism season, when flows are at their lowest.

With respect to *knowledge and information*, while there is a considerable amount of effort in improving monitoring and observation networks, access to information is seen as complex and uncoordinated. Actors at the cantonal level asserted that this was recognized and efforts were on going to generate central databases for hydrological information, but improving connectivity across different groups and administrative levels was a challenge.

The relevance of *networks* in the response to these events is highlighted by stakeholder comments that when extreme situations do arise, there is intensive contact with other stakeholders. This comes in different forms at the different levels. For example at the commune level, as part of their risk planning strategies, there is an "alarm group", which includes a number of different actors, some of whom are involved in water issues on a full-time basis, some of whom are volunteers. While a rich response network was discussed in relation to hazards (flooding, avalanches), relatively little exists across different stakeholder/sectoral groups for water use, outside of the different conventions between the municipalities and ski-lift owners (who manage the artificial snow production) or the hydropower companies.

The irrigation groups, known as *Geteilschaft/Gemeinschaft; Consortages*, which co-govern the water irrigation canals (*Suonen/Bisses*) (Reynard 2008), still exist in the Valais. There are currently about 706 km of canals in the Valais, with many being reinstated and repaired along with the accompanying organizations,

not only for tourist value, but also as a means to foster solidarity in maintaining infrastructure and minimizing costs as the local level.

Collaboration exists across different stakeholders, notably in the domain of research and monitoring collaborations. For example, hydropower companies partner with the federal research institutes to develop projections of impacts on glacial melt from climate change. The cantonal administration relies on private consultancies to measure, collect and provide data to them on water quality and quantity. At the local level, communal authorities use private consultancies to outsource aspects of EIAs and other reports/studies they are required to submit to the canton. This aspect concerning networks is also tied into the resources indicator, since at the local level these deliverables are outsourced because resources are limited. Additionally, cantonal authorities noted that financial resources at the commune level tended not to be sufficient to cover damage costs from flooding events such as the 2000 event in Baltschieder, near to Visp. In these situations, the canton or federal government needs to step in and cover a certain amount of the costs.

The relationship between the different *levels of decision-making* in is highly interesting for a number of indicators. Cantonal authorities consistently clarify that they can only take a "hands off" approach, using incentives and guidance to suggest water management methods on the lateral rivers. The Rhone, on the other hand, remains the responsibility of the canton. Interestingly, while the federal government has passed a Federal Ordinance on Water Provision during times of emergency, it has not been brought into effect in the Canton Valais.

Additionally, it is clear that no one person is really responsible for "water management" as a whole. At the cantonal level, people have their individual responsibility, with intermittent collaboration across the different offices. At the local level, the communal authority is generally responsible, with different competencies for different individuals. Since the communes tend to be so small, people know who they need to go to.

With regards to *flexibility*, one key area is the length of hydropower concessions. For example, in the communes of Les Bagnes, these will not to be renegotiated until 2040. Currently in times of stress, the municipal industrial service must informally ask the hydropower companies if it would be possible to do an exchange of water, which is possible at their "goodwill". For an actual renegotiation of the terms of the concession, they will need to wait until 2040.

Discussions pertaining to the influence of *experience* of past events were particularly interesting and rich. The role of prior experience in extremes and impacts of natural hazards was considered highly important in determining the preparedness for extreme events. The importance of prior events, such as the 1993 and 2000 floods, in the collective consciousness should therefore be potentially considered as important as professional experience and training. More generally, the knowledge and experience of historical shifts in the climatic and socioeconomic situation, and the fact that the Valais is the driest canton in Switzerland, has meant that the irrigation infrastructure is well developed. This means that the Valais is perhaps better positioned perhaps than other areas in Switzerland for coping with

drier, more stressed periods through the adaptations that stakeholders (mainly agricultural) have had to implement over the past decades (better irrigation technology and resurgence of the consortages) and centuries (development of the canals and consortages since the 13th century).

There is perhaps a need to focus on the broader implications of this in the planning for climate change impacts in the water sector, and in general. Since climate change impacts are seen to be pushing us beyond our range of experience, one question is how to build social resilience in the absence of prior experience of similar issues. This is particularly relevant for the tourist sector, since unlike the agricultural actors, the experience and knowledge of managing past change and uncertainty does not stretch back as far.

Leadership did not generate much discussion in interviews, except for the role of a certain individual in the cantonal administration for natural hazards, who is responsible mainly for overseeing avalanche preparedness. However, in the case of Les Bagnes, one can identify the important role the central organization, SIB, has played in creating a more integrated network for water provision. It may, therefore, be worth expanding on the understanding of *leadership,* so that it encompasses the leading role a centralizing local institution can play, not just individual leadership.

Issues of scale are relevant not only to *levels of decision-making*, but to other indicators as well, notably *networks* and *integration*. Politico-geographical scale is highly relevant to where water issues are experienced in the Valais and where they are not. In some villages, drinking water and irrigation water are taken from the same sources (mainly groundwater), which means that while one village may have no issues with conflicting uses (refer to the Le Châble example above), the next-door village will experience water scarcity during peak times of use, or low periods of precipitation. Scale plays a relevant role here on two counts. Firstly, the municipal level micromanagement means that neighbouring villages can experience highly contrasting management problems. Secondly, in this particular case, altitudinal and geographic scale directly affected the variety of sources Valaisanne communes can rely on.

The interviews showed that in practice there is a considerable amount of crossover between some of the indicators (i.e., *networks—knowledge—resources*; *resources—experience*; *integration—networks*), which will need to be addressed. It may also be required to rethink the underlying criteria behind an indicator such as *experience*, as to whether collective experience is a more driving factor than individual training, which could also be a feature of *resources.* Finally, two of the indicators, *leadership* and *resources* proved the most difficult in terms of eliciting rich responses as to their relevance in both managing the resource and the events.

Conclusion

This paper set out to discuss some of the issues in developing a deeper understanding of how to characterize and assess adaptive capacity to climate change in water governance arrangements. The discussion of the current state of

indicators on adaptive capacity suggests that there are a number of challenges in present assumptions, yet identifying and refining characteristics of adaptive capacity through interviews also proves testing.

The initial results from interviews in the Swiss case area suggest that is necessary to rethink some of the characteristics of the indicators. While further work needs to be done to refine and operationalize all the indicators, two of them need particular attention and possibly reassessment. Partly as expected, *leadership* is perhaps conceptually too vague to have significant analytical relevance for assessing the governance system. It would perhaps be better placed in disciplines more concerned with anthropology or broader social sciences. With regards to the *resources* indicator, it is particularly difficult to be able to meaningfully define whether the level of financing or human resources, training or general education is sufficient. It is also unclear how this could be more universally operationalized to be comparatively meaningful across the different case areas and beyond. Other studies do not seem to provide many answers here, since a great deal of data and indicators on *resources* tends to lie at the national scale (Brooks et al. 2005; Engle and Lemos 2010).

Future work will apply the methodology in the Chilean case area (which was delayed due to the earthquake) in order to generate a comparative analysis into the relevance of these indicators in a different socioeconomic and climatic context. This research does not aim to provide a broad panacea of adaptive capacity insights and recommendations for building adaptive governance, but instead to use comparative local experiences to better operationalize adaptive capacity, from which we can build our understanding of how to reduce vulnerability to future uncertainty and climate change. It is vital to provide not only local guidance, but to use comparative cases to see where a more holistic understanding of adaptive capacity itself can be built, and how relevant universal indicators can be to local issues such as water governance.

Additionally, future work must focus on better understanding the outcome of the reaction to and management of these events. This could allow us to infer whether change (in this case extreme events) is being managed in a way that enhances adaptive capacity or leads to a more negative outcome (Chapin et al. 2009). Future work will also encompass deeper analysis of the qualitative data, with the tool Atlas-TI, as well as using richer climatological and hydrological model data from the ACQWA project to build a better picture of climate impacts on which to map the vulnerabilities and adaptive capacity of the governance system.

The issue of scale is still problematic in the adaptive capacity literature. Empirical application in the contrasting case regions will address not only issues of verification, but equally of scale. While there is a growing literature on adaptive governance and adaptive management with respect to water resources, there is still a tendency for the respective disciplines of social science and climatology to remain within their respective niches. This is to the detriment of a more holistic understanding of challenges from climate change and the exploration of potential

responses to these threats or possibly opportunities. In this study, it has been attempted to explore ways of bridging this gap.

While this attempt may be a crude initial effort, it is hoped that it is a contribution to the understanding of how researchers need to start not only understanding the different languages of a multitude of different disciplines, but also should employ the tools associated with them within their own research to gain a more comprehensive understanding of the issues which are being researched. Finally, adding this extra layer of detail to the indicators will add clarity and a deeper understanding to their performance and the reporting of the results. While normative indicators can be useful, more analytical empirical studies need to assess how different determinants may contribute to building resilience across scales and sectors, in different forms of climatic extremes.

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