

Sustainable Development and the Adaptability of Social-ecological Systems

Theoretical Dimensions and Indicators of Adaptive Capacity

Introduction

Sustainable development remains an extraordinary challenge across the world. Population growth and economic development are increasing pressure on ecosystems. Intensive use of natural resources may deplete available stocks, and changes in land use through deforestation, agricultural production or urbanisation can profoundly modify ecological dynamics, resulting in the loss of important habitats and the services they offer to society (Aylward *et al.*, 2005). Decision-makers must deal with difficult trade-offs in a complex and inter-connected world which dynamics are difficult to understand and predict (Kemp and Parto, 2005). In this context, there is a growing interest internationally in making society less vulnerable to future environmental change and crisis, in particular climate change (OECD, 2011). The EU White Paper on Adapting to Climate Change for example aims to “*promote strategies which increase the resilience to climate change of health, property and the productive functions of land*” (European Commission, 2009).

In the academic literature, research on adaptive capacity has taken up the task of examining the characteristics of society increasing its capacity to deal with environmental and social crisis. It is grounded in the view that social-ecological problems may be so complex and multi-dimensional that perfect solutions may not exist at any one time. The challenge is to improve the ability of society to respond to on-going and expected change and crisis, while allowing flexibility for managing yet unknown ones. With its outlook on future change and on the capacity of social-ecological systems to sustain essential functions, adaptive capacity is a core dimension of sustainable development.

The paper contributes to the first objective of the Summer School, namely “Sustainable Development: Historical and Theoretical Overview). It introduces participants to the concept of adaptive capacity, and aims to foster discussion on the contributions that research in adaptive capacity and sustainable development can bring to each other. The paper first briefly presents how the idea of adaptability is embedded in sustainable development. The development of “adaptive capacity” as an academic concept is then traced in the literature on hazards, adaptation to climate change, and natural resource management. In particular, this section shows how adaptive capacity is underpinned by two school of thoughts, i.e. vulnerability and resilience research. The following two sections show how studies identifying and measuring the determinants of adaptive capacity have been influenced by these two schools of thought. The paper concludes on future prospects for studying the adaptability of social-ecological systems.

Sustainable development and adaptability

Sustainability has slowly become a normative dimension of good governance in modern society (Jordan, 2008). The Brundtland report popularised the term through its definition of sustainable development. It identified sustainability as the moral obligation to meet the demand of current generations and maintain the capacity of future generations to meet theirs (WCED, 1987). Several principles to encourage sustainable development were presented in the report, such as stronger integration of social and environmental issues in economic development and effective citizen participation in decision-making. In policy for example, Dovers (1999) argued that sustainability requires better policy integration across sectors, portfolios and jurisdictions, and providing clearer policy directions and statutory mandates to improve institutional capacities across space and time (e.g. extend time horizons). Sustainability moves attention from end of pipe solutions to more in-

depth, structural change of social systems.

The report emphasised that, to become more sustainable, social and technological systems must change and search continuously for new solutions to better take into account the opportunities and limitations set by the natural environment. In particular, it stresses the need for “*an administrative system that is flexible and has the capacity for self-correction*” (WCDE, 1987). Sustainable development is therefore essentially a process of reflexive change, posing the question of how to introduce responsiveness and adaptability in policy, law, institutions and organisational capacity (Dovers, 1999). Kemp and Parto (2005) call for “*programmes for system innovation*” that accompany systemic transitions across society. Instead of relying on rigid performance standards and solutions, governance for sustainable development requires “*policy-making frameworks that actively seek to identify, nurture, and coordinate action for more sustainable technological niches, accompanied by co-evolving societal processes characterised by continuous changes in formal and informal institutions*”. For them, anticipatory, long-term change embedded in reflexive and adaptive planning is needed.

The concept of adaptability in social-ecological systems, in particular adaptive capacity, is taking these ideas forward. Past research on adaptive capacity has focused mainly on the adaptability of society to natural hazards and climate-related risks (e.g. floods, climate change impacts). Clearly, these environmental stresses can undermine sustainable development, and authors have called for further dialogue between climate change and sustainable development research (e.g. Swart *et al.*, 2003). The IPCC recognises the importance of these links, in particular to foster benefits on long-term poverty reduction and environmental protection through climate change mitigation and adaptation measures (Yohe *et al.*, 2007). However, adaptive capacity should be understood more broadly than solely to climate change impacts. Recent developments, in particular arising from resilience research, provide new conceptual and methodological approaches to studying adaptability in society, as presented in the rest of this paper.

Adaptability in social-ecological systems

The concept of adaptability in social-ecological systems is commonly identified in several streams of research, the main ones being hazard research, climate change adaptation and natural resources management.

Hazard research originated in geography in the post second-world war period (White, 1974), and posited that natural hazards were a function of physical processes and human decision-making (i.e. where decisions lead to increased exposure to natural hazards). A core theoretical orientation underpinning hazard research is the idea of “adjustment”, a reference to the belief that society and individual citizens could adapt and respond to hazards by developing and adopting a broad range of adequate management techniques (Burton *et al.*, 1993). The 1970s and 1980s saw the emergence of a critique driven by sociologists which highlighted how social constraints may constrain decision-making (Watts, 1983). Hazards were not created by individual decisions free of choice, but by the way society functioned, i.e. the web of cultural, economic and political processes influencing human behaviour. The risk to a hazard is therefore conceptualised as the combination of the exposure to the hazard and the “vulnerability” of a population, i.e. its susceptibility to damage or injury. Vulnerability research in the hazard tradition is traditionally focused on social, political and economic factors influencing the creation of environmental hazards and disasters.

By the 1990s, hazard research was becoming increasingly intertwined with research on the adaptation to climate change, which main concern is the ability of society to respond to the increasing threat of climate change impacts (Eakin and Luers, 2006). It posited that adaptation

could be either (i) reactive to a stress that had already occurred, or (ii) anticipatory to potential, future stresses (Smit *et al.*, 1999). Climate change research was concerned by the possibility of maladaptive strategies, and a core question was to identify how adaptation could be sustainable. Analytical focus was on developing appropriate decision-making frameworks, with the help of climate change models to estimate future biophysical and societal impacts and identify adequate policy responses. Unlike traditional hazard research focused on constraints and path-dependence, climate change research was interested in choice and pro-active change.

A rich academic debate ensued in the 1990s and 2000s on the relationship between concepts such as hazard, risk, exposure, sensitivity, adaptation and vulnerability (Adger, 2006; Gallopin, 2006; Smit, 2006). It is in this context that attention to a society's "coping" and "adaptive" capacities against environmental change and crisis –and how it could be increased– grew. Several vulnerability frameworks were developed (e.g. Turner *et al.*, 2003; Brooks *et al.*, 2005; Fussler and Klein, 2006) leading to the now commonly used definition for vulnerability as being "*the measure of risk combined with the level of social and economic ability to cope with the resulting event, that the combination of exposure, sensitivity and adaptive capacity to the hazard*" (Adger, 2006; Gallopin, 2006; Smit, 2006). Adaptive capacity, defined by the IPCC as "*the ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behaviour and in resources and technologies*" (Adger *et al.*, 2007), is seen as the property of a system that reduce vulnerability by modulating exposure and sensitivity to a hazard (Engle, 2011).

The concept of adaptability in social-ecological systems did not solely arise from research on hazards and the adaptation to climate change (linked by the concept of vulnerability), but also from research on natural resources management. In his studies on ecosystem dynamics and how to improve their management, Holling (1973) posited that, instead of assuming perfect knowledge and predictability, management regimes should acknowledge the complexity of ecological systems, and the uncertainties inherent in managing them. Management should aim to increase the overall "resilience" of ecological systems, that is their ability to "*absorb disturbance and reorganise while undergoing change and maintaining in the process key functions, structure, identity and feedbacks*" (Holling, 1978; Lee, 1999). Management regimes should be flexible and adaptive, i.e. regularly adjusted to changes in the ecological system being managed and managers' understanding of it (Nelson *et al.*, 2007). Early adaptive management research focused on how specific management programmes at local and regional levels impacted ecological systems and their resilience.

The late 1990s and 2000s saw a broadening application of the idea of adaptability into broader social systems (Folke *et al.*, 2002; Gunderson and Holling, 2002; Dietz *et al.*, 2003; Folke *et al.*, 2005; Folke, 2006). As conceived by Holling, resilience is the capacity to fluctuate within boundaries and avoid thresholds beyond which systems may collapse. Later developments recognise the existence of multiple stability domains. Adaptive capacity of social-ecological systems is seen as the capacity of actors to manage and influence transitions (i.e. moving from one system state to another) (Nelson *et al.*, 2007). In a resilient social-ecological system, new system state is based on "desirability", and is therefore socially constructed and negotiated (Hatfield-Dodds *et al.*, 2007). For Folke *et al.* (2005), social-ecological systems should aim for sustainable development, in particular based on integrated, ecosystem-based management. Scholars applying resilience theory to governance systems call for quasi-autonomous decision-making units operating at multiple spatial scales (Duit *et al.*, 2010). This allows individuals, communities and organisations to develop self-organising capacities, and better respond to relevant environmental change and crisis. It also helps spread risks in social-ecological systems, and allow the failure of individual units without compromising the whole (Huiteima *et al.*, 2009).

Overall, current understanding on adaptive capacity can be broadly differentiated between a "vulnerability" and a "resilience" perspective (Engle, 2011). Each traditions have their strengths

and weaknesses (Miller *et al.*, 2010; Engle, 2011). Analytical interest in vulnerability research tends to be on the interests, values and knowledge of actors within a web of social, political and economic processes, in particular how social structure constrain their capacity to adapt (and therefore increase their vulnerability). Vulnerability approaches have therefore been better at understanding social factors reducing adaptive capacity, but less so at ecological factors. Analytical interest in resilience research is on systemic interactions between bio-physical and social elements (e.g. thresholds, feedbacks, etc), in particular cases of systemic reorganisation following a shock or crisis. Because of the complexity of these interactions, most studies have focused on local community natural resource management. Resilience approaches have therefore been better at understanding coupled ecological and social processes increasing adaptive capacity at local, but less so at the complex web of higher social, economic and political factors influencing adaptive capacity.

Research on adaptive capacity is now at the juncture of these two research traditions, and combined frameworks, theories and measurements methods are needed (Miller *et al.*, 2010; Engle, 2011). The next section explores in more depth the determinants of adaptive capacity identified in both literature.

Determinants of adaptive capacity

Building on hazard and adaptation to climate change research, the IPCC identified in its 3rd Report the following determinants of adaptive capacity (Smith *et al.*, 2001):

- Resources: the availability of resources and their distribution across society;
- Technology: the ability to develop and implement innovative technological options;
- Knowledge and skills: a good awareness of the necessity to adapt, the capacity to collect, understand and assess new knowledge, and the skills to implement new ideas;
- Infrastructure: the characteristics of existing infrastructure, including land use patterns,
- Institutions: the ability of institutions to regulate individual entitlements, enable collective action, and mobilise resources, knowledge and skills;
- Equity: the equitable access to resources, technology, knowledge and skills

Many other indexes of adaptive capacity in this school of thought were developed in the 2000s (e.g. Yohe and Tol, 2002; Vincent, 2004; Brooks *et al.*, 2005). Yohe and Tol (2002) and Tol and Yohe (2007) use the IPCC synthesis to identify 8 determinants. They argue that adaptive capacity is dependent on the “weakest link”. For example, despite having all the necessary resources to adapt, a rich region is likely to have low adaptive capacity if it doesn’t have appropriate knowledge or institutions. Many studies point out to other factors than those of the IPCC. Brooks *et al.* (2005) for example identified governance, civil and political rights and literacy as important indicators. For Haddad (2005), a society’s “aspirations” (e.g. policy objectives) are as important as its structural characteristics. For example, a society aiming to maximise the welfare of its citizens will perform differently than one that aims to reduce the vulnerability of its poorer citizens.

Some research suggests the existence of generic determinants (namely education, income and health) and more specific to the particular stress/impact considered (e.g. institutions, knowledge and technology) (Adger *et al.*, 2007). Generic determinants are important to build adaptive capacity to yet unknown stresses, while specific ones improve the responses to well-identified ones. The existence of generic determinants is however fiercely debated in the academic community. In particular, many studies stress the significant influence of scale and context on adaptive capacity. Determinants at national level are unlikely to be the same as those at community or individual level. National adaptive capacity is usually found to be related to economic wealth (i.e. GDP per capita, inequality in the distribution of income), universal health care coverage, education, universal access

to information, environmental capacity, and political system in place. The adaptive capacity of local communities may vary with social capital, values, customs and levels of cognition, while, at individual level, adaptive capacity can vary with age, class, gender, health and social status. Nations with high adaptive capacity may have regions and individuals with very little adaptive capacity. Determinants are not independent from each other, but interact and combine in unique ways in different social-ecological contexts and scales.

Most studies to date have taken a “vulnerability” tradition, assuming that adaptive capacity was also dependent from the same variables and determinants as vulnerability. Some critics stress that the vulnerability framework is too “asset-oriented”, focusing on static indicators rather than on processes and functions (Jones *et al.*, 2010). Scholars bring attention to the resilience literature, more oriented towards rich, place-based descriptions of the dynamic processes underpinning adaptive capacity. Studies on adaptive management and related theoretical development (see e.g. environmental self-governance of Ostrom, 1990) emphasise community-led natural resource management (Folke *et al.*, 2005; Nelson *et al.*, 2007). Communities may be more knowledgeable of changes in local ecological conditions than centralised bureaucracies, and more prompt in responding to change and crisis. Drawing on several case-studies of natural resource management at community level, Folke *et al.* (2003) identified 4 dimensions to adaptive capacity and 14 determinants (Table 1). Most of them appear as normative principles focusing on social processes, for example learn from crisis, sustain social memory, or encourage complementarity of knowledge systems.

Table 1. Dimensions and determinants of adaptive capacity (Folke *et al.*, 2003)

Component	Subcomponent
Learning to live with uncertainty, change	<ul style="list-style-type: none"> • Learn from crises • Expect the unexpected • Evoke disturbance
Nurture diversity for reorganization and renewal	<ul style="list-style-type: none"> • Nurture ecological memory • Sustain social memory • Enhance socio-ecological memory
Combine different types of knowledge for learning	<ul style="list-style-type: none"> • Combine experiential and experimental knowledge • Integrate knowledge of structure and function • Incorporate process knowledge into institutions • Encourage complementarity of knowledge systems
Create opportunities for self-organization	<ul style="list-style-type: none"> • Recognize relationship between diversity and disturbance • Deal with cross-scale dynamics • Match scales of ecosystems and governance • Account for external drivers

As discussed in the previous section, resilience theory would call for distributed power across society to increase its adaptability (e.g. independent community-level decision-making). However, this does not necessarily call for extreme cases of decentralised and fragmented structures of decision-making. Higher organisational levels in governance are valued because they can improve responses to ecological dynamics that cross social and administrative boundaries (Folke *et al.*, 2005). The aim is to reach a balance between decentralised and centralised control, ensure synergies between organisational levels, and avoid conflicting interventions. Participative processes and co-management are called for in order to increase the capacity of actors not only to mobilise knowledge and resources for action (Olsson *et al.*, 2004; Hatfield-Dodds *et al.*, 2007), but also strengthen collaboration between stakeholders (Armitage *et al.*, 2008). Stakeholder collaboration is fundamental in the resilience tradition of adaptive capacity because social change is not through sanctions and incentives, but also through social learning, i.e. changing social actors’ relationships, understanding, values and norms.

Ludi *et al.* (2012) evaluate adaptive capacity in several case-studies of adaptation and maldaptation

in rural africa. They examine the processes leading to the uptake of assets. They use the following determinants:

- Asset base: availability of key assets that allow the system to respond to evolving circumstances;
- Flexible forward looking decision-making and governance: the system creates an enabling environment to foster innovation, experimentation and the ability to explore niche solutions in order to take advantage of new opportunities;
- Innovation: the system is able to anticipate, incorporate and respond to changes with regards to its governance structures and future planning;
- Knowledge and information: the system has the ability to collect, analyse and disseminate knowledge and information in support of adaptation activities;
- Institutions and entitlements: existence of an appropriate and evolving institutional environment that allows fair access and entitlement to key assets and capitals.

They found that moving from an asset focused framework to one focused on processes changes the type of advice for building adaptive capacity. For example, instead of providing resources, technologies and skills, a better objective might be in creating the networks, trust and ability to innovate, select, and implement new technologies, knowledge and skills.

In an original attempt to provide a policy relevant framework for analysing adaptive capacity, the World Resource Institute has developed the National Adaptive Capacity Framework (WRI, 2009). It consists of a set of questions to support the development of an adaptation strategy, and to encourage the development of adaptive capacity while assessing it (i.e. learning by doing). Indicators are developed into procedural and analytical questions that should indicate necessary reforms. The process should be transparent and participatory in order to embed learning across stakeholders.

Overall, the vulnerability and resilience approaches provide complementary information on the determinants of adaptive capacity, although little cross-fertilisation and combined assessments are yet available. Different conceptual origins and research traditions explain this gap (Miller *et al.*, 2010). This is clearly exemplified in the methodologies used to identify and measure determinants of adaptive capacity, as presented the next and last section.

Measurement of adaptive capacity

The vulnerability and resilience approaches have usually used different epistemological and methodological approaches. With its roots in sociology, vulnerability research has been largely influenced by constructivism, although positivism also represented a strong research stream in hazard research, in particular behaviouralism (Burton *et al.*, 1993). With its roots in natural resource management, resilience research has used more positivist approaches (Miller *et al.*, 2010).

Past attempts at measuring adaptive capacity in the vulnerability approach can be broadly divided into deductive and inductive studies (Inkle, 2011). Deductive approaches identify determinants of adaptive capacity based on existing knowledge, and select indicators that most accurately represent those determinants. An example of a deductive approach is the vulnerability-based National Adaptive Capacity Index (NACI), developed by Vincent (2004; 2007) for African countries. She identified 5 determinants measured by 9 quantitative indicators, including for example standard of living (i.e. % people under poverty line) and change in urban population for measuring the determinants “economic well-being and stability”. A local alternative was also developed, the Household Adaptive Capacity Index (HACI). There, indicators are based on a mixed qualitative and quantitative assessment of household surveys and in-depth interviews.

The deductive approach has two main disadvantages. First, the selection of determinants can be based on existing knowledge but in many cases knowledge is missing as to the exact nature of these determinants and their relationship with adaptive capacity (Inkle, 2011; Engle, 2011). For example, the role of civil society in decision-making has been identified as a key determinant of adaptive capacity. However, some theories about democracy and the state would value civil society and interest-groups, but others do not. The selection of variables, indicators and their relationship with adaptive capacity may therefore be dependent on deep-seated assumptions and worldviews, and, at times, be somewhat intuitive. Second, indicators must be sensitive to variation, but broad enough to be transferable between countries (Jones *et al.*, 2010). However, data is often lacking, and some determinants may be difficult to represent as indicators (Inkle, 2011; Engle, 2011).

The inductive approach usually identify a large number of potential variables deductively, and use expert-judgement, principal component analysis, or correlation with a measure of harm (e.g. economic loss, mortality, people affected, people injured or left homeless) to identify significant determinants (Inkle, 2011). Alberini *et al.* (2006) and Sietshing (2006) use for example expert judgement based respectively on a conjoint choice survey and consensus-based workshops. Cutter *et al.* (2003) selected 250 variables based on a literature review. They reduced them to 85 after test of multicollinearity, to 42 after normalisation, then to 11 using principal component analysis. Brooks *et al.* (2005) first used a literature review, expert judgement and data availability to select a short list of 46 variables. The list was then reduced to 11 significant determinants using correlation with mortality.

The inductive approach suffers from three main weaknesses. First, the reliance on an initial proxy of vulnerability (e.g. harm) is somehow at odds with the final purpose to measure vulnerability through its determinants (Engle, 2011). Second, the selection of the initial proxy of vulnerability is usually an intuitive decision, and rarely based on a full characterisation and measure of harm (Inkle, 2011). Harm has multiple dimension that may not be well represented in available databases (e.g. psychological stress). Also, harm is usually related to fast-onset hazards rather than slow changing conditions. Third, statistical models can provide meaningful results when systems can be narrowly defined with few variables and when sufficient data is available (Inkle, 2011). These conditions are rarely met in studies of adaptive capacity of social-ecological systems because such systems are open, complex and poorly understood. This issue can be reduced when examining a specific system responding to a specific stimuli in a local context.

Most studies of adaptive capacity grounded in vulnerability assessment have been quantitative cross-country comparisons (e.g. Brooks *et al.*, 2005; Alberini, 2006). Some studies develop composite measurements of adaptive capacity, others aggregated measures. Studies with aggregated measures tend to first build composite measures, and then use expert-based or stakeholder-led weighings for the aggregation process. Inkle (2011) criticises aggregated approaches because existing knowledge on adaptive capacity is too limited to provide robust information on the relative importance of different determinants, as well as the combined impact of their interactions on overall adaptive capacity.

Most research in the resilience tradition has used a deductive approach whereby adaptive capacity of social-ecological system is characterised against a predetermined set of theoretical determinants and used case-studies to determine their adaptive capacity (e.g. using theory to provide policy recommendations) (Engle, 2011). Fewer studies have tried to measure adaptive capacity inductively to build theoretical understanding of adaptive capacity, notable exceptions being early case-studies of local community natural resource management by Berkes *et al.* (2003) and Olson *et al.* (2004). Because of the focus on complex social-ecological interactions, studies using a resilience approach have mainly used in-depth case-studies to capture dynamic, rich processes and interactions (see e.g.

Ludi *et al.*, 2012 as discussed above). Fewer attempts have been made to build generalised, quantitative measurements of adaptive capacity, as observed in the vulnerability tradition.

Gupta *et al.* (2010) adaptive capacity wheel is a good example of an assessment framework built deductively, but using a mixed qualitative-quantitative approach (Figure 1). 6 variables and 22 determinants were developed deductively to measure the adaptive capacity of institutions (i.e. the inherent characteristics of institutions that empower social actors to respond to short and long-term impacts either through planned measures or by encouraging creative responses from society). Measurement is principally qualitative (e.g. rich description of attributes), but an attempt is made to use scoring and weighing to derive comparable strengths and weaknesses between determinants and between social-ecological systems onto which the wheel is applied. In their study, evaluation was carried out through multiple independent assessment by experts, but they believe the use of participatory methods is also possible.

Figure 1. The Adaptive Capacity Wheel developed by Gupta *et al.* (2010)

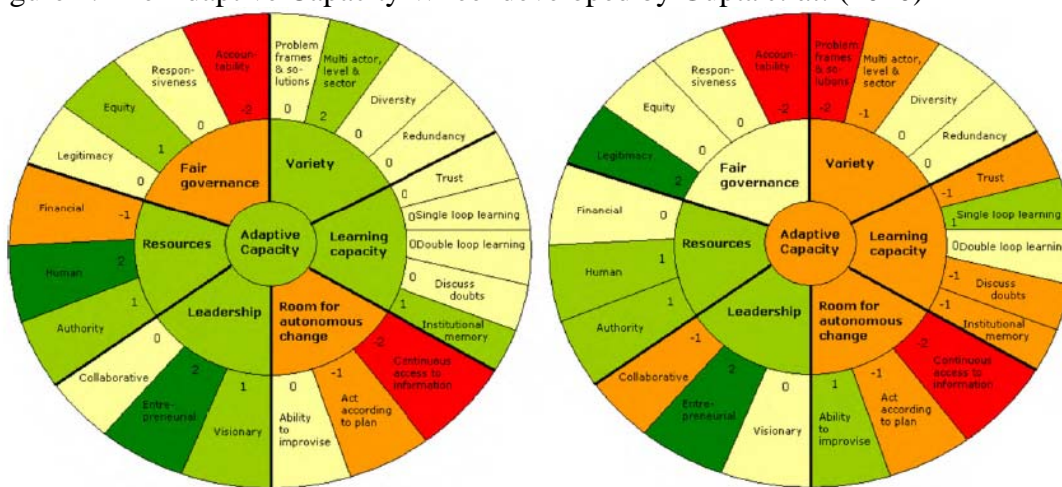


Fig. 2 – Application of the Adaptive Capacity Wheel to Delft (left) and Zaandam (right).

A generic issue affecting studies in both vulnerability and resilience traditions is the temporal dimension of adaptive capacity. On the one hand, adaptive capacity has been defined as a latent characteristic of social-ecological systems. Therefore, its measurement necessarily requires using proxies (events) in the past to identify which determinants are significant. On the other hand, social-ecological systems are dynamic and open-ended (Folke, 2006). Future events may far exceed stress levels of past ones or may be more gradual than disasters or hazards (usually used to assess adaptive capacity). Berman *et al.* (2012) recently highlighted the need to differentiate between coping capacity to current (climate-related) stress and adaptive capacity to future (climate change) stress. Coping capacity is the ability of actors to draw on available skills, resources and experiences as an immediate response to manage adverse stressor shocks brought about by current (climate) variability. Adaptive capacity is the ability to prepare in advance for stresses and changes and to adjust, respond and adapt to the effects caused by the stress associated with future (climate) change. Overall, examining the past and current situation is therefore likely to provide a partial, biased, and possibly misleading, view of future vulnerability and adaptive capacity (Vincent, 2007). Future research could use scenarios (e.g. Moss *et al.*, 2001) or modelling methods such as agent-based models to improve our understanding of these dynamics in complex social-ecological systems.

Conclusion: learning from the Summer School

Sustainable development is a process of societal change in a world characterised by imperfect knowledge, and complex, open-ended dynamics. The adaptability of social-ecological systems or their ability to manage change and perturbations is therefore critical to sustainable development. Studies arising from vulnerability and resilience research offer some conceptual basis and methodological strategies to identify and measure determinants of adaptive capacity. However, uncertainties arising from issues of scales, contexts and imperfect knowledge of social-ecological systems make it difficult to develop robust, policy-relevant indicators. Some researchers therefore doubt the validity or even usefulness of existing indicators for adaptive capacity (Inkle, 2011).

Research on adaptive capacity is now at a critical juncture between vulnerability and resilience traditions. Future assessments of adaptive capacity can build on conceptual and methodological complementarity. However, other research areas may provide useful lessons on how to manage issues of complexity, scales and contexts in social-ecological systems. In particular, much effort has been targeted at developing robust and policy-relevant measurements of sustainable development. Given the relevance of research on adaptive capacity for sustainable development, and their similar objectives and interests, there is potential for cross-fertilisation with past and current thinking on sustainable development.

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