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Topic (1) The framing adaptation problems and goals

Title:

TURNING POINTS IN CLIMATE CHANGE ADAPTATION

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Abstract

Concerned decision makers increasingly pose questions as to whether current management practices are able to cope with climate change and increased climate variability or whether alternative strategies are needed. This signifies a shift in the framing of climate change from asking what the potential impacts of climate change are to asking what can be done and when. This paper contributes to the debate on adaptation to climate change by focusing on the specific situation where, due to climate change, current governance agreements will no longer be able to meet their objectives and alternative strategies have to be considered. If such a situation is thinkable, climate change becomes particularly relevant to decision makers. We call this situation an 'adaptation turning point'. The question is how much longer current policies and management practices are expected to suffice and when adjustments will be required. The assessment of adaptation turning points translates uncertainty about the extent of climate impacts into a time range over which it is likely that specific impacts occur and which can be used to take adaptive action. This paper will explore adaptation turning points as a concept for assessing and communicating the implications of climate change. It discusses the theoretical basis (how to define, identify and quantify adaptation turning points) and case evidence of adaptation turning points in Europe. Experience so far is that expressing uncertainty in time (when will a critical point be reached) is easier to understand for stakeholders than the more typical presentation of the amount of change in a certain projection year. In addition, the assessment of adaptation turning points allows for a meaningful dialogue between stakeholders and scientists about the amount of change that is acceptable, when conditions could be reached that are unacceptable or more favourable, how likely these conditions are and what adaptation pathways to consider.

1 Introduction

Adaptation has become an integral part of climate change policy (Adger *et al.*, 2007). The ultimate scale of the challenge will largely be defined by the development of our world's economy and greenhouse gas emissions reduction, which is uncertain, suggesting that risk averse planners should prepare for rises in global mean temperature of 4°C or more (Parry *et al.*, 2009; Betts *et al.*, 2011). Adapting to such conditions would be challenging at best (Smith *et al.*, 2011), and may face practically insurmountable physical limits in many places due to loss of ecosystem services and interacting impacts (Warren, 2011).

The ability of socio-ecological systems to cope with global change is shaped by complex, interactive and non-linear dynamic processes (Folke, 2006). Thresholds, amplifying feedbacks and time-lag effects are widespread and make the impacts of global change hard to predict, difficult to control once they begin, and slow and expensive to reverse once they have occurred. In trying to understand the dynamics of climate impacts for which adaptation would be a response, thresholds or tipping points have recently garnered much attention, a trend reviewed by a.o. Russill and Nyssa (2009). Tipping points are associated with the shift of a system between alternate regimes. Lenton *et al*. (2008) evaluated potential policy-relevant tipping points in the earth system under climate change. They conclude that, while climate change assessments have emphasized the significance of multiple drivers, the potential importance of thresholds, amplifying feedbacks and time-lag effects has been underestimated. These effects are a major concern for scientists, managers and policy–makers, because of their potentially large impacts on natural resources, ecosystem services and human well-being. Global change shifts the sustainability challenge from preserving natural resources for future generations to strengthening resilience and adaptive capacity in socio-ecological systems. Decision-makers and concerned citizens urgently demand reliable science-based information to help them respond to climate change impacts and opportunities for adaptation (Dessai *et al.*, 2004). Levin and Clark (2010) identified adaptability in the light of tipping points and thresholds as a key research challenge in sustainability science. In their ability to trigger major change as well as challenge current management practices, thresholds and tipping points can be a threat as well as an opportunity for current management. Importantly, they can open the way for debating new solutions.

The recent attention to thresholds and tipping points in physical and biological systems suggests that it may be important to explore the existence of such phenomena in the social and political systems within which adaptation policies play out. The concept of 'adaptation tipping points' was advanced for a policy study of long-term water safety in the Netherlands (Kwadijk *et al.*, 2010). It proved successful to assess and communicate water related risks and has since become one of the scientific concepts underpinning the Dutch long-term water strategy. A similar planning approach was developed and tested in the Thames estuary (Lavery and Donovan, 2005; Smith *et al.*, 2011).

Underlying this work is the recognition that climate change only becomes relevant to policy makers if it threatens current management objectives or results in conditions that society perceives as undesirable. If such a situation is thinkable, next to knowing the extent of the threat, at least equally important is to know when and how likely it is that the situation occurs. This way, it is not the exact figure of - for example - rising sea levels that matters as much as the question of whether or not our current management practices or policies are still satisfactory for the changing climate, and if so, for how long, and when adjustments will be required. In other words, when are "turning points" in the socio-ecological system reached? Identifying such turning points can help determine how best to anticipate them. It is the combination of top-down impact assessment of global change threats and bottom-up elicited socio-political preferences and risk perceptions that makes the proposed concept unique and timely (c.f. Dessai *et al.*, 2007).

In this paper, we aim to explore 'adaptation turning points' associated with climate change and the implications of such turning points for adaptation planning. We choose the term 'turning point' to avoid confusion with the popular term 'tipping point' that people associate with major change in the biophysical system. Against this background, we can summarize the overall objectives of our work:

- The scientific objective is to gain a better understanding of the role of turning points in adaptation to climate change and to elaborate the possibility and consequences of using adaptation turning points for the identification of structural properties and mechanisms that make socio-ecological systems robust and/or receptive to external shocks or internal perturbations, i.e. sustainable in the face of uncertainty and change;
- The practical objective is to explore whether adaptation turning points are a useful concept for assessing and communicating the implications of climate change, which can help decision makers in developing and prioritising adaptation strategies.

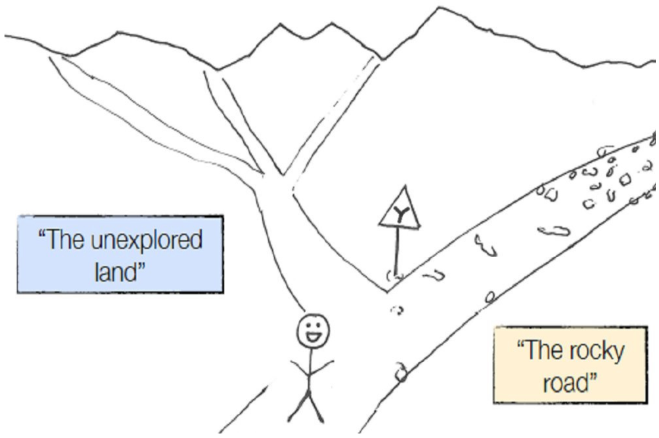
A paradigmatic example of an adaptation turning point would be the point at which the use of land for a particular purpose (e.g. agriculture) ceases to be economically viable, and the adaptation challenge shifts from making the farming more resilient to climate variability, to managing land-use change towards some other purpose (e.g. nature and/or water retention), and helping the farmers to find alternative livelihoods (e.g. in tourism or health services). This would change the institutional setting for decision-making (such as from the agricultural ministry to the environment and social affairs ministries), and require different decision-support (such as from plant research to health services studies).

The adaptation turning point perspective is chosen because it is a timely concept for bringing together concerns and insights about *how much* stress a system can absorb before losing its function, *when* this is likely to happen, *why* people may care and *what* can be done. The paper will build on cases from Europe, primarily from the MEDIATION FP7 project. Insights gained from the analysis of adaptation turning points in selected case studies can shed new light on the design of institutions, policies, and practices that support climate adaptation in specific situations.

The paper first introduces methodological issues (how to define, identify and assess turning points, (Section 2), next Section 3 introduces case evidence of climate change turning points in Europe. Section 4 summarises the tentative conclusions of our work. Thus the paper aims to contribute to the on-going debate on thresholds and tipping point dynamics and how to deal with (climate adaptation) turning points and thresholds in socio-ecological systems. Experience from our cases so far shows that the assessment of adaptation turning points stimulated the dialogue between the research and policy community about *the amount of change* that is acceptable, *when* conditions could be reached that are unacceptable or more favourable, *how likely* these conditions are and *which adaptation pathways* to consider.

2 Defining and assessing Adaptation Turning Points

in this paper we introduce 'adaptation turning points' as a means to appraise and communicate the implications of climate change, in support of decision makers in adaptation planning. We define an adaptation turning point as *a situation in which a socio-political threshold is reached, due to climate change induced changes in the biophysical system.* Socio-political thresholds here include formal policy objectives as well as informal societal preferences, stakes and interests, such as willingness to invest and protection of cultural identity. The assessment of adaptation turning points gives information on whether and when current management may fail and other strategies are needed. It asks whether and when climate change results in conditions that actors find unacceptable or more preferable. For example, when the revenue from current agricultural crops falls below a certain level or when new economic activities become attractive.



The turning point illustrated

An adaptation turning points assessment starts from the perspective that a socio-ecological system is managed to maintain conditions for socio-environmental activities. Climate change affects the system, resulting in a possible failure of the current management (the "rocky road") or in opening up other more preferable management perspectives (the "unexplored land"). At that moment an adaptation turning point is reached. This does not mean that management is impossible and that we face catastrophic consequences. Yet, it implies that alternative strategies or policies have to be considered. Faced with potential failure of the current management regime, actors may also be more inclined to take adaptive action. From this viewpoint, adaptation to climate change becomes relevant for policy makers if it challenges current management and asks for alternative policy decisions. Reaching adaptation turning points can have biophysical, technical, socio-economic and political causes. This requires both a profound system understanding as well as the discussion of control variables that society should not transgress. Ultimately, the question is a normative one – how much risk is society willing to take in approaching, and perhaps inadvertently crossing, a threshold (Steffen, 2009)? In this perspective, adaptation turning points are an emergent property of actor activity in socio-ecological systems. At their heart lie trade-offs between efficiency, robustness, adaptability and vulnerability (performance) of socio-ecological systems across temporal and spatial scales.

Building on previous studies (e.g. Kwadijk *et al.*, 2008; Kwadijk *et al.*, 2010; te Linde and Jeuken, 2011), we have used the following practical steps for the assessment of adaptation turning points and adaptive responses:

1) *Scope the assessment*: Identify the target region and socio-ecological sectors of concern.
2) *Identify key potential impacts of climate changes*. 2a) Make a long list of possible consequences of climate changes for the region and the sectors of concern, 2b) Prioritise climate change trends and impacts based on potential severity and likeliness (use trends + extreme scenarios).
3) *Determine socio-political objectives of concern*: Select indicators and threshold values for potential impacts on sectors and regions: determine which situation is acceptable for actors according to: a) Analysis of policy objectives, standards or administrative arrangements, b) Public opinion, and/or c) Historic analysis.
4) *Determine adaptation turning points*: Determine how much climate change a sector can handle and when a thresholds value is reached. Ask: Which climate conditions are critical for reaching objectives? What are climate conditions beyond which the current strategy fails? Methods: compare with design criteria; consult experts / representatives from different sectors; assess

historical variation of boundary conditions. Next, translate turning points to timescale: Use climate scenarios to assess when the turning points may occur.

5) *Determine alternative adaptation strategies*: Assess which strategies actors may use to respond to adaptation turning points. Consider strategies that offer an alternative to current management or additional measures to postpone or resolve a turning point (methods depend on scale, score alternatives against reaching or failing policy targets). Assess how easy it is to switch between strategies in time (flexibility, 'no regret').

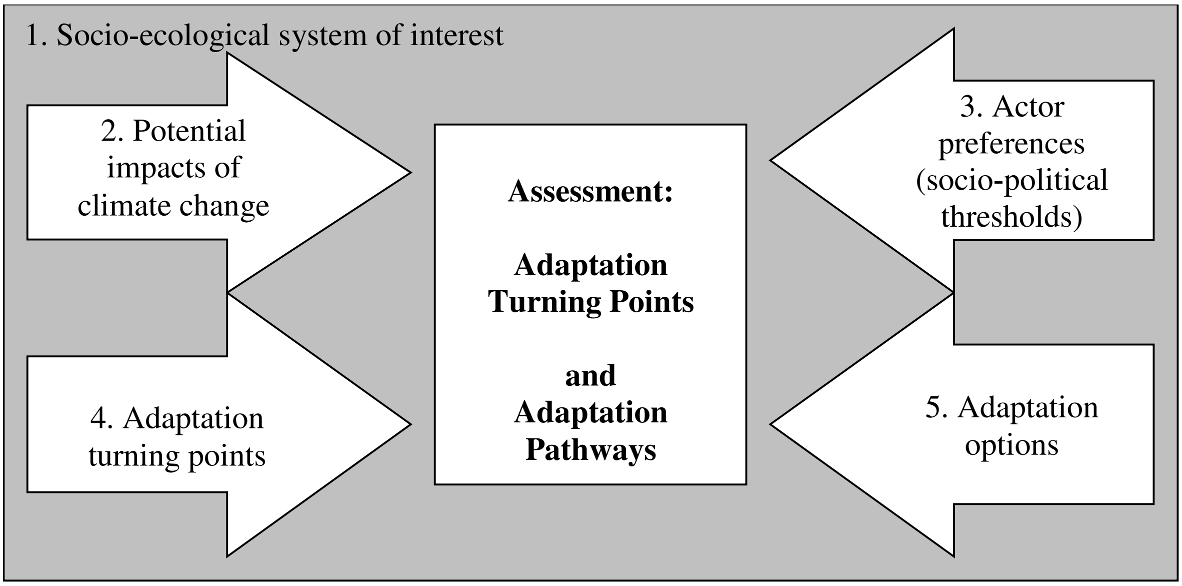


Figure 1: Elements of the assessment op adaptation turning points and adaptation pathways

3 Case studies

This section briefly introduces three cases in the assessment of adaptation turning points. The full assessment is available with the authors.

3.1 Turning points in salmon restoration programmes, Rhine river basin

This case study investigates, if high water temperatures [and low water discharge] can trigger an adaptation turning point for the Rhine salmon policy in the period until 2100. Furthermore, we reflect on the use of the adaptation turning point concept for evaluating nature policies. Atlantic salmon was a common anadromous fish species in the Rhine, but extinguished in the past. A reintroduction programmes exist since the 1990s. The conservation plans do not consider climate change impacts. Projections for the Rhine basin show increases in winter discharge and decreases in summer discharge. Additionally, atmospheric and water temperature will rise. This may affect the propagation and spawning migration of the salmon, and thus hamper the success of the reintroduction programme and achievement of the associated policy objectives. Thus an adaptation turning point may be reached, requiring additional action or a shift in policy objectives.

A turning point for salmon policy depends on a complex of scales and factors. A statement about whether or not an adaptation turning point will be reached will always have to indicate clearly with respect to what set of policy objectives and societal preferences. Also from an ecological perspective, it is difficult to formulate hard bio-physical thresholds for salmon propagation. Thresholds that have been included in policy (such as water temperature ranges) may ultimately not be indicative fully reliable for ecological success (or failure of the salmon to re-establish).

Salmon policies at the Rhine scale do have specific objectives, such as 7,000 to 21,000 upstream migration individuals per year and undisrupted migration possibilities up to Basel. Next to climate change these objectives depend on a multitude of other factors that cannot easily be detangled from the climate effect. Policies failure depends on the effort of a multitude of organisations, operating at different scales in the Rhine river basin. At the national scale the setting of temperature standards is required. These standards must be set following the Water Framework Directive and relate to the ecological quality of the river. But in practice the standards prove to be the result of negotiations in which socio-economic considerations have the lead and the interest of salmons play an indirect role at best. Until recently, temperature thresholds related to salmon migration and survival were seldom exceeded, this was not a problem. At many scales, efforts are made anyway to provide the right habitat and connectivity conditions for salmon.

Our first analysis of adaptation turning points suggests that in the future, climate change may significantly affect the success of for salmon reintroduction and does imply the need to rethink salmon policies or to start thinking about adaptive action. So, adaptation turning points related to salmon migration and survival are real. However, to operationalize the concept and assess the implication of reaching them in more detail, the assessment of adaptation turning points presented in this section identified the following complications:

- In the case of salmon policy, few well defined ”absolute” turning points exist, because of complex and indirect links between temperature changes and salmon migration and survival. The assessment of adaptation turning points may be more meaningful in cases where policy norms (like salmon reintroduction) are less ambiguously linked to higher policy objectives. From this perspective, the case of flood safety, for which the concept of adaptation turning points was originally developed, may be more successful in yielding communicable results than that is the case of improving ecological status, because flood frequency can be more directly linked to precipitation changes.
- Turning points for engineered systems (like dikes, dams, gates, etc.) are constructs fixed into norms and standards. Definition of such norms and targets for natural systems seems more complicated and less attempted in policy.
- Available knowledge did not allow for assessing turning points in detail. Knowledge gaps include:
    - Data availability: Modelling of Rhine water temperature has only recently started and no time series are available yet.
    - System understanding: the relationships between upstream migration at different river sections and climate related parameters such as water temperature are only partially known. This also holds for ecological responses, such as the behaviour of salmon under stress.

3.2 Turning points in wine production in Tuscany, Italy

This case study explored wine production in Tuscany, Italy under climate change. Farmers in Tuscany are already facing the consequences of climate change. Agricultural land use has created a unique landscape in Tuscany that is both productive and internationally recognised for its beauty. Thus, agriculture has both an economic, and environmental and landscape value in Tuscany. A key question is whether climate change will make farmers change grape varieties or reduce grape production areas and switch to other livelihoods. There is an increasing interest of stakeholders for adaptation to climate change, where it is feared that changes in the land use could have detrimental effects on the landscape, and therefore on tourism and quality of living. The main research questions for this case are: what are possible adaptation turning points in the region, where one or more of the stakes defining and delimiting the wine production in Tuscany are compromised. How likely are they to occur and when? More specifically, this case explores turning points related to stakeholder preferences and adaptive action:

- (when) does wine production in its current form become financially unviable in the region?
- (when) does adaptation become attractive? In consultation with stakeholders two adaption actions are studied: moving to higher altitudes or changing variety.

The Tuscan analysis shows that turning points in wine cultivation related to temperature and water availability may well occur before the end of this century. Around the same time that present production may start to become unviable, the production at higher elevation becomes more attractive, opening up an avenue of adaptive action. Such an adaptive action will not be taken lightly and the decision will have to be studied in the light of many factors, including the existence of other options to adapt and avoid fundamental turning points like moving to other livelihoods. The following preliminary observations are made and will be pursued in future work. The adaptation turning points concept can be:

i) stakeholders motivated, since the stakes that are defining and delimiting activities in a system such as wine production in Tuscany can be defined by stakeholders;

ii) scalable, since it can be adopted at supranational level, where policy makers are willing able to define the political boundaries of a system, down to local, where communities are jointly defining the stakes of a system they related to;

iii) flexible, since it can be based on scientifically measured parameters, such as economic feasibility, as well as on other thresholds (e.g. the conservation of a traditional cultivation, disregarding the economic profitability), and may be modified and adjusted to changing situations;

iv) useful, as a discussion tool, both for scientist willing to communicate their insights, and for decision-makers at any level addressing adaptation issues.

3.3 Turning points in flood safety and nature conservation, Wadden sea region, the Netherlands

This assessment of adaptation turning points is carried out for the Dutch Wadden region. The Wadden region is one of the world's largest tidal areas of its type consisting of mudflats borders by barrier islands in the North and the coast of the mainland in the South. It has been on the Unesco World Heritage List since 2009. The assessment focuses on water management in the Wadden region, as addressed in the Dutch Delta Programme. The central goal of the Delta Programme in the Wadden region is to warrant long-term flood safety and to establish a monitoring programme for the impact of climate change on the ecology of the Wadden Sea in particular. Special attention goes out to adaptation strategies based on natural process that can strengthen ecological resilience in the area and facilitate sustainable human use. The case study discusses adaptation turning points for water management in the Wadden region following the three pillars of current water management: long-term safety, resilient nature and sustainable human use.

It is very likely that more sediment is needed in the Wadden Sea to compensate sea-level rise (Kabat *et al.*, 2009; Oost *et al.*, 2009). This is expected to result in increased erosion of the islands and additional requests for sand replenishment (Ministerie van Verkeer en Waterstaat, 2008). There is a limit to the rate of sea level rise that the natural sedimentation in the Wadden Sea can compensate for. If sea level rise is not compensated by sedimentation, tidal exchange through inlets increases, which leads to sand sequestration in ebb-tidal deltas and (further) erosion of adjacent barrier shorelines. Increased erosion and channel formation can undermine sea walls. The combination of projected sea level rise, storm occurrence and heavier storm surges compromise the safety of ports and industry in unembanked areas outside the sea walls (Oost *et al.*, 2010). A special case is the Ems, a tidal river on the border of the Netherlands and Germany. Due to its location, dredging and other interventions the tidal build up of water is already high (Talke and de Swart, 2006). The estuary has a significant role in energy production and transport. Increased storm frequency will endanger infrastructure in the estuary. The impacts of temperature rise and precipitation change on safety and the primary sea walls are less well understood and presently expected to be low (Oost *et al.*, 2010).

The assessment shows that policy objectives are relatively clear for water management. For nature protection they are less well developed, with different views among actors on e.g. 'natural quality' of the wadden region. Long-term socio-economic objectives (vision for the region) are absent from the Delta Programme. It has been a conscious decision for the programme to focus on safety issues, yet this makes integral evaluation of adaptation strategies more difficult and may result in overlooking more integral adaptation strategies, opportunities for mainstreaming and buy-in of a actors beyond those already involved in water management.

With respect to safety, the assessment illustrates that changes in wave climate can cause failure of primary sea walls before sea level rise is projected to do so, due to the large uncertainty for changes in wave climate. Interestingly this scenario parameter is not provided by the Royal Netherlands Meteorological Institute (KNMI) due to the large uncertainty in the projections and left out from the scenarios developed for the Delta Programme. This signifies the focus in the programme on the 'known unknowns'. The assessment underlines the importance of assessing turning points in relation to a combination of factors. This, however, complicates the storyline and there is a trade-off with the strength of the assessment in communicating implications of claimte change.

4 Discussion, conclusions and future work

This section summarises the conclusions reached so far with respect to the adaptation turning point concept. It first discusses the different steps of proposed for an adaptation turning point assessment (see Figure 1). Next it lists strength and weaknesses identified in the cases and future steps to be taken.

Scoping the assessment

A comprehensive scoping of the assessment is an important first step that often gets insufficient attention in climate assessments. It helps to identify stakeholders, policy plans and to determine the spatial and temporal boundaries of the assessment that may be larger than initially perceived due to the characteristics of climate change. Starting from an existing policy process is likely to facilitate the engagement of actors, but may limit the turning points under consideration. Existing policy processes provide an well-communicable starting point for framing the assessment, yet a comprehensive analysis of climate change impacts and possible adaptation turning points may require putting this policy process in a wider perspective, including the exploration of the various ways stakeholders frame the issues to be addressed.

Climate scenarios and impacts

Climate scenarios and impacts are relatively well documented in all cases. This allows for different approaches to be used in the assessment, such as a more qualitative approach (Wadden case), a quantitative scenario approach (Rhine case) and a risk-based approach (Tuscany case). Yet, arguing from the perspective of policy goals and stakeholder preferences, it is found that some critical scenario parameters are not included in the scenarios developed for adaptation policy planning, for a variety of reasons. In the Wadden case, for example, storm intensity was found to be an important parameter. This parameter is however not provided by the Royal Netherlands Meteorological Institute (KNMI) and in the Delta scenarios that are prepared for the long term water safety policy (the Delta Programme). The reason is that scientific uncertainties are considered to be too large to justify projections. An additional complication is that the important assessment of the timing of adaptation turning points is often not yet possible because climate projections are only provided for one or two future years rather than as a function of time.

Socio-political stakes of concern

Policy goals are not always clearly defined, especially with respect to potential impacts of climate change. Different stakeholders have different parameters by which they measure the success or failure of policy. National goals can be disconnected from local preferences. Policy objectives may be relatively clear for a sector like water management, yet less developed for other sectors in the same case study (e.g. nature protection). The method may inappropriately focus attention on the most clearly defined stakes.

Adaptation Turning Points

The occurrence of turning points is often found to depend on a complex of scales and factors. A statement about whether or not an adaptation turning point will be reached will always have to indicate clearly with respect to which set of policy objectives and societal preferences. For ecological systems it may be more difficult to formulate thresholds than for technical systems. Thresholds that have been included in policy (such as water temperature ranges) may ultimately not be indicative for ecological success (or failure, e.g. of the salmon to re-establish). The more indirect stakeholder preferences are related to climate change, the more difficult the determination of adaptation turning points is. For example, in the case of the salmon additional uncertainties are introduced by the adaptability of the species (adjusting to higher temperatures, finding cooler water refuges). The assessment of adaptation turning points may be more meaningful in cases where quantified policy standards are less ambiguously linked to higher, often qualitative policy objectives. From this perspective the case of water safety, for which the concept of adaptation turning points was originally developed, may be more successful in yielding communicable results (as the performance of water infrastructure is directly linked to climate variables) than the case of improving ecological status (which has more complex linkages to climate variables).

Adaptation strategies

The adaptation turning point concept allows for nesting adaptation options within a longer time frame (c.f. Smith *et al.*, 2011). This is particularly useful when developing strategic alternatives for the management of a system under climate change and when considering adaptation options with a longer decision and implementation lifetime (more than 10 years, e.g. moving viticulture to higher altitudes in the Tuscany case). The concept can also be used to assess thresholds in taking adaptive action (e.g. Tuscany case). It is important to note that an adaptation turning point can also be avoided by a shift in policy objectives and socio-political preferences. For example, in the Rhine case by the reformulation of policy norms (e.g. lowering safety standards) or societal objectives (e.g. embracing the sturgeon instead of the salmon as an icon for ecological quality and focus of restoration programmes). How to link adaptive strategies to avoiding or postponing adaptation turning points is an important knowledge gap that is still to be addressed in detail in our cases. Next to avoiding or postponing adaptation turning points, there are other reasons to decide on adaptation strategies. For decision making these will have to be mapped too.

Strength and weaknesses of adaptation turning point concept from the cases:

Strength / opportunity	Weakness / Threat
The Adaptation Turning Point approach: • Is appropriate to synthesize available information for the prioritization of research and adaptation planning. • Is more policy-oriented and stakeholder motivated than typical impact and vulnerability assessments. Actors can define the stakes that are defining and delimiting activities and are to be considered in the assessment. • Uses scenarios not to predict the future, but to make uncertainties visible and provide an idea of possible developments that should be taken into consideration for political decision-making. • Is flexible in considering a range of socio-economic objectives. • Encourages discussion with society about (un)acceptable change and definition of critical indicator values.	*The Adaptation Turning Point approach:* • Focuses on existing management objectives. Unknown impacts and new challenges may be overlooked. • Complexity increases with multiple drivers or in situation where there is an indirect link with climate change, limiting the usefulness of the concept. At present only relatively simple / mono driver thresholds have been identified with sufficient certainty for policy support. • Requires socio-political thresholds that are often ill-defined. • Loses simplicity for communication for less-well defined thresholds and turning points with multiple drivers illustrations.

Due to its novelty, so far, both for the researchers and the stakeholders, a fully satisfactory assessment of adaptation turning points has proven difficult in the cases studied for this paper. Yet, initial experiences with the approach clearly resonate with stakeholders and we feel that the adaptive turning point analysis surfaced new questions, which are very relevant for adaptation planning and we are encouraged to further explore the concept. Future steps we plan to take include:

- Try to close the gap between available climate parameters and (the probability of exceeding) policy norms and stakeholder preferences in most of the cases;
- Strengthen the assessment of adaptation strategies in relation to avoiding or postponing adaptation turning points, policy goals and other stakeholder preferences;
- Further test the value of an adaptation turning point assessment in communication with stakeholders;
- Reflect on what (combinations of the) characteristics of socio-ecological systems in the cases studies lead to adaptation turning points;
- Study whether the process of adaptation itself contributed to or created adaptation turning points;
- Try to identify classes of adaptation turning points from the case studies;
- Revise the steps of an adaptation turning point assessment based on lessons from case studies (develop good practice guidance).

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