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Opportunities for water governance adaptation to climate change

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1 Introduction

1.1 Background

Over the past few decades, the problem of climate change has attracted a particular attention. Climate change is largely associated with an increasing concentration of greenhouse gases in the atmosphere, causing a global warming effect. The reason for this is the retention ability of the atmosphere that impedes emission of heat radiation from earth to space. Scientists have high confidence that these changes in the atmospheric composition are human-induced. The leading international organization in the assessment of climate change, Intergovernmental Panel on Climate Change (IPCC), proposes several scenarios for global warming until 2100, predicting a temperature increase in the range of 0.8 – 3.5°C above the 1990 average.

In this regard, climate change is expected to cause multiple effects on the environment that in large part are being assessed as negative: more intense heat waves, changes in precipitation patterns, accelerated glacier melting and sea level rise as well as changes in other climate-relevant indicators are anticipated. All these changes eminently affect societal and environmental systems.

Climate change has already sparked a great concern around the world since its consequences are observed at the regional and local scale. For instance, last year an immense river in Canadian Yukon vanished in four days due to a melting glacier, affecting human and ecological communities around the river. Scientists argue that this first observed case of a "river piracy", diversion of a stream's headquarter into another that usually happens over long timescales, is a dramatic evidence of extreme changes due to global warming. Current scholarship also warns of increasing frequency and intensity of such extreme events. Although one has initially placed a greater emphasis on mitigation strategies to deal with climate change (i.e. reduction of greenhouse gases concentration in the atmosphere), adaptation is currently becoming a necessary response to deal with climate impacts, and thus an integral part of the global climate change discussion.

1.2 Problem statement

Adaptation to a changing climate is not a very new approach: it had been recurrently observed through the history of human existence. However, a changing environment and more stresses of non-natural origin, i.e. human activities, reduce

the ability of social and ecological systems to adapt. In addition, uncertainty associated with climate change poses challenges for traditional resource governance approaches. The adaptation literature yet reports on the growing evidence of various factors that impede climate adaptation.

Adaptation to climate change appears thus as a major challenge. In this vein, opportunities to adapt are certainly worthwhile exploring. That is however problematic: a well-established conceptualization of opportunities for adaptation is still missing. The present study aims to address this gap by defining and characterizing opportunities to climate change adaptation.

1.3 State of the art and aimed contribution

The concept of adaptation opportunities is yet an emerging one. At present, there is no sufficient evidence on which factors enable the adaptation process and which effects they exactly have. This can be explained by the fact that adaptation currently represents rather a reactive response to climate change impacts. The existing studies on adaptation mainly conclude with some short suggestions how to support adaptation processes, largely in respect to observed adaptation barriers and are mainly context-specific.

Up to date the most comprehensive perspective on adaptation opportunities is presented in the Fifth Assessment Report of the IPCC. Adaptation opportunities are differentiated there between enabling conditions and ancillary benefits of adaptation. The report provides an overview of both types of opportunities and presents an aggregative categorization of enabling conditions for adaptation, bringing together the existing literature documenting on individual opportunities. It advocates that opportunities to adaptation should be examined in the regional context since adaptation predominantly occurs at the region and local scale.

Therefore, there is no common broad conceptualization of opportunities to climate change adaptation that would thoroughly characterize and examine opportunities context-independent to facilitate adaptation broadly. This thesis is intended as a contribution towards that end by providing a well-grounded picture of adaptation opportunities, revealing their characteristics and examining their effects. Conceptualizing adaptation opportunities has potential implications for the

understanding of adaptive capacity and related to that decision making in the adaptation process.

1.4 General approach

Since adaptation opportunities are poorly examined, the present study is designed as exploratory. Exploratory research implies gaining knowledgeable insights on the examined issue and development of new ideas and assumptions, appearing as the most relevant for defining new concepts. This is certainly helpful for developing a knowledgeable perspective of adaptation opportunities that facilitates their further theoretical conceptualization.

To explore adaptation opportunities the synthesis of a wide range of studies reporting on opportunities is insightful. For examining adaptation opportunities more thoroughly a systematic literature review method is used. This method particularly allows for the integration and expansion of research evidence on the issue.

Due to a manifold character of adaptation, it is however problematic to address opportunities abstractly. In that regard, it is preferable to focus analysis on one particular sector, where opportunities to adaptation are expected to be revealed and are essential due to reported existing barriers. In this view, water governance in river basins seems to be promising for studying opportunities to adaptation, since much research work had been conducted with regard to water management and governance to draw on. Moreover, many rivers are globally affected by climate perturbations that are expected to be drastically magnified. Those will affect water quantity and quality through reducing run-off contribution from glacier and snowmelt, shifts in seasonality, and increasing frequency of flood and drought events. The adverse effects of climate change impose significant risks for social and ecological systems. In this perspective, the role of governance is critical to address this challenge.

To explore adaptation opportunities in the context of water governance a systematic analysis of 26 selected case studies on water governance adaptation in river basins worldwide was conducted. This helped to develop a more concrete understanding of adaptation opportunities and their implications for adaptation decision making. By exploring opportunities to adaptation, this study can rely on

previous work of EISENACK and OBERLACK (2017), which explains adaptation barriers in water governance of river basins.

1.5 Research question

By conducting a systematic review of the adaptation literature and of selected case studies on water governance adaptation in river basins, the study aims at inductively constructing a well-grounded picture of adaptation opportunities. Pursuing this main objective the present thesis aims to study the following central research question:

- How can opportunities in the governance of adaptation be defined and characterized?

To answer this question the thesis also seeks to study more specific questions:

- What adaptation opportunities do occur in the governance of climate adaptation?
- Which implications do opportunities have for adaptation decision making in general?
- In what way do opportunities correlate to adaptation barriers?

1.6 Summary and structure of the thesis

The concept of adaptation is currently an integral part of the global climate change discussion. An increasing empirical evidence demonstrates a challenging nature of climate adaptation, which results in the demand for solutions and strategies to facilitate adaptation processes. In this regard, opportunities to adapt are certainly worthwhile to explore. However, at present a well-established conceptualization of opportunities for adaptation is still missing. The current study aims at addressing this gap by examining and defining adaptation opportunities. To explore and to provide a comprehensive perspective of adaptation opportunities, a systematic review of multiple case studies on water governance in river basins worldwide is performed. This helps to reveal what opportunities occur in the governance of climate adaptation, in what way they are related to adaptation barriers and what they mean for adaptation decision making.

To study these questions the thesis first provides a comprehensive theoretical background on climate change adaptation. It outlines main aspects of its governance and conducts a review of existing barriers in the adaptation governing process. The

following chapter also presents reviewed findings on adaptation opportunities from other studies and proposes a new perspective on their categorization.

The third chapter introduces the methods and materials used for the data analysis. The forth chapter systematically presents the main results of the study. The results are mainly introduced with the use of tables and the thematic content analysis. Here, the focus is set on the most frequently found opportunities to climate adaptation.

The fifth chapter summarizes the key results, presents the limitations of the study and discusses counterfactuals in observations of adaptation opportunities and their possible implications for decision making and future research. Finally, the last chapter gives a summary and draws on main conclusions.

2 Theoretical framework and concepts

2.1 Introduction

The chapter provides a theoretical background necessary for understanding and examining opportunities to climate change adaptation. First, it defines climate change adaptation and gives insights on its intentions, key features and dimensions. Within the scope of the present study, adaptation is characterized as a social process. It implies that adaptation requires action and interaction between various elements of an affected system. In this regard, adaptation is considered as a governance problem. Due to a multifaceted character of adaptation, this problem is addressed in relation to water governance in river basins.

The role of governance for adaptation decision making is shown from different perspectives. Adaptation governance is characterized as complex in that it coordinates multiple interactions, which shape adaptation and its outcomes. These interactions can both hamper or enable adaptation processes. To provide an overview of the factors that hamper adaptation process, the concept of adaptation barriers is presented next. Finally, the reviewed findings on adaptation opportunities from other studies are introduced in a new perspective. It demonstrates that understanding of opportunities goes beyond their classic interpretation as solutions to barriers in the adaptation literature.

2.2 Defining adaptation to climate change

2.2.1 The concept of climate change adaptation

Climate change adaptation is currently appearing on the governance agenda worldwide. Yet the term of adaptation was used in natural sciences, namely in biology and ecology, and was referred to adjustments of biological species or the whole ecosystems to changing natural environmental conditions. Further, the term was used in different sciences, such as sociology, geography, anthropology and many others, keeping its initial ecological principles (SCHIPPER and BURTON 2009). Applied to human systems the term adaptation reflected "new and improved methods of coping with the environment" that allowed cultures to survive, distinguishing the humans' ability to manage adaptation (SMIT and WANDEL 2006, p.283, SMITHERS and SMIT 1997). Nowadays, the term is largely used in relation to climate change and its variability. In this context, it refers to adjustments in social,

economic and ecological systems to climatic stimuli and their impacts (KLEIN et al. 2014).

The importance of adaptation in the context of climate change was acknowledged in two ways. First, since 1992 adaptation has been defined in the United Nations Framework Convention on Climate Change as one of the (policy) response options to climate change in line with mitigation (SCHIPPER and BURTON 2009). Despite the increasing practices to cut down greenhouse gas emissions through different mitigation strategies, human-environmental systems are still being exposed to threats related to present and expected impacts. In this context, adaptation as an additional and necessary option aims at responding to climate change impacts. Along with that, adaptation aims to benefit from the opportunities related to changing climatic conditions (SMIT and PILIFOSOVA 2007). This understanding of adaptation as a part of policy evaluation corresponds to a normative analysis, which aims at prescribing and/or evaluating adaptation measures to facilitate adaptation (SMIT et al. 1999).

On the other hand, the extent to which human-environmental systems are vulnerable depends on their exposure to climate change impacts as well as on their ability to adapt to them (SMIT and PILIFOSOVA 2007). In this regard, adaptation is an essential part of climate impact assessment in terms of defining. Impact assessment is used to assess the thresholds and risks on the global scale for formation of a general greenhouse gas reduction policy as well as to develop adaptation options on the local and regional scale (PITTOCK and JONES 2000). This logic corresponds to a positive analysis, which is meant to predict the circumstances under which adaptations can be expected as well as to estimate their likelihood (SMIT et al. 1999).

Adaptation involves primarily taking practical actions (e.g. technological innovations or supplementary infrastructure projects) to address the risks and impacts imposed by climate change. In the context of water management it is, for example, desalination of seawater as an adaptive option to meet an increasing water demand as well as construction of dykes against flooding or widening of riverbanks (WILDER et al. 2010). Besides measures of a physical character, adaptation also includes changes in practices and decision-making processes to deal with climate change impacts (e.g. approval of National Climate Change Action Plan and adaptation policies, changes in livelihood practices). In certain cases, adaptation

involves rather complex solutions that include both physical responses as well as changes in ecosystems and in practices. In this context, a novel concept of first- and second-order adaptation is calling for considering adaptation as a chain of processes: first-order adaptation includes measures to directly response to climate impacts, while second-order adaptation are additional processes to deal with the impacts associated with the first-order adaptation (BIRKMANN 2011).

Consequently, adaptation implies changes in the adapting system in response to climatic stimuli. Addressing adaptation comprehends consideration of characteristics attributed to a climatic stimulus, an impacted system and respective responses to this climatic stimulus (three dimensions of adaptation according to SMITHERS and SMIT 1997).

In this way, adaptation can have various forms and take place under different processes (SMIT et al. 2000). Adaptive responses may differ along with the scale, time, outcome, effect of adaptation, etc. An important distinction is in accordance with the intent of an adaptation action and its timing: adaptation can occur autonomously (naturally) or planned (policy-induced) as well as proactively (anticipatory to climate changes) or reactively (after a climate disturbance) (SMIT et al. 2000). Preparatory adaptations imply iterative processes on a longer view that allow integrating new information as it becomes available (HILL and ALLAN 2014). By contrast, reactive adaptations are attributed to fast responses that include prompt decisions in order to reduce the damage caused by climate extremes.

Adaptation to climate change includes adaptation to climate variability and related extreme events in contrast to merely focusing on average annual conditions (SMIT and PILIFOSOVA 2007). This means that changes in climatic conditions refer to changes in their mean. In other words, changes in nature and frequency of conditions, including extreme events, matter. SMITHERS and SMIT (1997, p.21) define the scope of such climatic stimuli of adaptation, including “short-term extremes, gradual changes in long-term average conditions, greater variability within the range of “normal conditions”, changes in types of extreme events, changes in frequency, magnitude and distribution of extreme events”. Climatic stimuli are usually differentiated according to their magnitude, spatial, temporal or causal characteristics.

Finally, characteristics of a system of concern are also important. Since the current study analyses human induced adaptations, in terms of scale it can be an individual or the whole community that adapt as well as it can refer to the managed ecosystem, the whole region or sector (SMIT et al. 2000). Regardless of its scale, each impacted system or society possesses characteristics that directly influence the way it will be affected by climate stimuli and the way adaptation will be occurring.

The extent to which systems are overall potentially able to adapt to climate impacts is determined by its adaptive capacity (PITTOCK and JONES 2000). Adaptive capacity depends on institutional, economic, social, cultural, technological and other factors that may increase or reduce the efficiency of the adaptation process. Thus, "adaptations are manifestations of adaptive capacity" (SMIT and WANDEL 2006, p.286). Adaptive capacity is context-specific and varies across space and time as well as across sectors and different actors (SMIT and WANDEL 2006). The scales of adaptive capacity, i.e. adaptive capacity of an individual that adapts, of a group of individuals, of a region or of a country, in which individuals operate, are interdependent (SMIT and PILIFOSOVA 2007). Adaptive capacity can be analysed in regards to a shorter-term capacity, implying the ability to survive (SMIT and WANDEL 2006). It can also refer to a longer-term capacity, involving more sustainable adjustments that would allow enhancing the ability of the system to cope with extreme climate manifestations that deviate from the norm (SMIT and WANDEL 2006, SMIT and PILIFOSOVA 2007). Referring to the former, some researchers apply the term "coping ability" in order to differentiate it from the intrinsic character of adaptive capacity (SMIT and WANDEL 2006). Adaptive capacity of a system is not static and react to the changes in its determining factors, thus increasing or decreasing over time (SMIT and WANDEL 2006). The factors that determine adaptive capacity are independent and have different effects depending on the context.

Many characteristics of a system shape its adaptive capacity. Such commonly used terms as "sensitivity", "vulnerability", "robustness", "resilience", "resistance", "responsiveness", "adaptability" and some others overlap each other in their conceptualization (SMIT et al. 2000). A differentiation of these terms is not the objective of the study; nevertheless, some of these characteristics are worth mentioning. For instance, understanding of vulnerability is important when considering adaptation as a part of climate and risk assessments. Vulnerability of a

system is an extent to which a system might be exposed or sensitive to hazardous climate stimuli and is able to adapt to it (SCHERAGA and GRAMBSCH 1998). Systems are thought to be sensitive to climate change and its variability to the extent they can be affected by its impacts and vulnerable to the extent they can be damaged (SMIT and PILIFOSOVA 2007). The interacting environmental and social elements of a system determine its vulnerability. The factors that cause the system's exposure similar to those that determine adaptive capacity are often interdependent, dynamic in their variation over time and space, and are context-specific (SMIT and WANDEL 2006).

2.2.2 Adaptation of water resources to climate change

Climate change adaptation depends on a wide array of factors and its interpretation may differ against the field (natural or social science) and purposes of the research. Within the scope of the present study adaptation is characterized rather as a social process concentrated on human adaptation, i.e. individual or collective actions designed to adapt to climate variability. Adaptation is then considered as not only a natural scientific or a pure technical problem, but involves social change and interactions. This implies that adaptation is considered in the present study as a governance problem.

In the climate-change literature that focuses on the analysis of human adaptation, adaptation is often considered as a process, through which people or their actions and behaviours reduce the losses and benefit from the opportunities associated with natural variability in climate (KATES et al. 2012, BURTON 1992). EISENACK and OBERLACK 2017 interpret adaptation as an individual or collective action that leads to changes in the affected system in response to former or projected climate impacts. In the present study, interpretation of adaptation is similar to foregoing definitions as well as to that of the IPCC. Adaptation is related to individual or collective actions at different scales of decision making, which implies changes in the affected system that intend to prevent and/or deal with present or future climate impacts as well as to preserve valuable resources.

The capacity of actors to manage and govern the state of a system to adapt is a key element to adjust to adverse impacts imposed by climate change and its variability (HILL 2013). More specifically, the analysis of adaptation focuses on the mechanisms, through which individual or collective adaptive actions are chosen and

implemented. It also explores how these choices are contingent on the resources, actors' knowledge, available information and relations with formal and informal processes (EPSTEIN et al. 2014). The latter, institutional and governing mechanisms (e.g. rights, policies, formal and informal practices and procedures, legislative frameworks) that prescribe interactions are shown to be particularly important (ADGER et al. 2007, COLEMAN 2011, ENGLE and LEMOS 2010, HILL 2013).

These mechanisms represent a complex phenomenon and its analysis in general terms appears to be too heterogeneous. In this regard, it is preferable to focus analysis on one particular sector. In this view, adaptation of water resources in river basins seems to be promising for studying adaptation since much research work had been conducted with regard to water management and governance to draw on.

Rivers are globally exposed to climate variation, which affects water availability and quality (e.g. water temperature and turbidity) through decreasing runoff due to the changing seasonality in precipitation and snowpack melting as well as due to more frequent and severe drought and flooding events. Even relatively small changes in temperature are expected to lead to a 10 – 40% increase in average river flows in some area and a 10 – 30% decrease in others (SADOFF and MULLER 2009). This leads to significant changes in water supply while other drivers, such as population growth, land use change and various development patterns, shape the a rapidly increasing demand in water resources.

Adapting river basin systems to climate change impacts is crucial since water as other natural resources can trigger conflicts over its use, and unlike other natural resources is essential to existence and maintenance of all living organisms, including human populations (MOSELLO 2015). Managing water resources in river basins is a crosscutting issue. This implies complexity in terms of including different sectors, scales and domains, meaning that there are mutual interdependencies among different actors with various interests and views that need to be coordinated (EDELENBOS and TEISMAN 2013). In this way, adaptation in river basins appears to be challenging.

From this perspective, focusing on the analysis of adaptation opportunities in the water sector is insightful since opportunities to climate adaptation are expected to be revealed and are essential due to existing barriers. The adverse effects of climate

change impose significant risks for social and ecological systems in river basins, and the role of governance is critical to address this challenge.

2.3 Governing climate change adaptation

Governance can be generally understood as "ways of steering and management of parts of society in response to the emergence of societal problems" (BIESBROEK 2014, p.3). The term "governance" is more comprehensive than the one of "government" as such since it involves both state and non-state actors participating in decision making. This is related to the evolutionary transition from conventional centralized and more formalized regimes of governance towards decentralized and less formalized bottom-up approaches that resulted in the networking processes of private and public actors (MOSELLO 2015). From this perspective, a categorization of governance broadly differentiates between monocentric and polycentric types (BIESBROEK 2014).

Monocentric governance is related to a hierarchical mode of decision making. This refers to command and control governance, where the state outlines the course of actions. This type of governance is usually challenged by its lack of responsive capacity and flexibility (PAHL-WOSTL and KNIEPER 2014). Polycentric governance contradicts a conventional centralized approach by involving "many centres of decision making that are formally independent of each other" and that are coordinated by a common set of rules (OSTROM et al. 1961, p.831). Hence, coordination emerges "from interactions rather than being imposed by one powerful actor" (PAHL-WOSTL and KNIEPER 2014, p.141). Polycentric governance regime is recognised to be important in governing environmental resources. The reason for this is that it leads to increasing resilience and capacity to deal with different kind of shocks, including climate change and its variability (PAHL-WOSTL and KNIEPER 2014). Polycentric governance is closely related to the concepts of multilevel and network governance (BIESBROEK 2014). However, regardless manifold advantages of polycentricity it can equally challenge governance, resulting in establishment of unclear and scattered responsibilities among various actors. Some scholars have argued that while climate change mitigation appears to be subjected to national and supranational competence, considering mitigation as "technological or fiscal measures aimed at certain economic sectors"; climate change adaptation seems to be

manifested rather locally and by a wide range of actors involved (WILSON and TERMEER 2011, p.151).

The role of governance for adaptation can be considered from different perspectives. For instance, in the welfare economics framework the role of governance is multifaceted. On the one hand, it results in developing adaptation policies aiming at reducing exposure and improving the capacity of a governed entity (OBERLACK and NEUMÄRKER 2013). In a similar vein, government can exercise various policy instruments to encourage adaptation. On the other hand, it is meant to assure a favourable environment for private adaptations (e.g. maintaining legal equilibrium of markets or providing financial means for research and education on climate change related issues) (OBERLACK and NEUMÄRKER 2013). From the institutional economics perspective, the role of governance also differs. It includes setting favourable preconditions for autonomous adaptations, distribution of power among actors as well as coordination between numerous jurisdictional levels (OBERLACK and NEUMÄRKER 2013).

Institutional settings, which include formal and informal "regularized patterns of behaviour", determine the way governance functions (GIANSANTE et al. 2002, p. 523). Institutions provide structure, instruments and basis for problems resolution, and reduce transaction costs associated with societal decision making. Depending on the structure, institutional and governing mechanisms can both impede and enable adaptation, i.e. "the performance of adaptive strategies and governance systems depend upon their fit with the attributes of the complex and dynamic social-ecological environment in which they operate" (EPSTEIN et al. 2014). For instance, OBERLACK and NEUMÄRKER (2013) differentiate institutional change, i.e. adjustments of institutions to new conditions imposed by climate change, among main characteristics of institutional systems that facilitate or impair adaptation. They also consider an institutional fit with environmental changes as well as flexibility of institutional structures as crucial characteristics of governance in the context of climate change adaptation (OBERLACK and NEUMÄRKER 2013).

Governance of climate change adaptation appears to be predominantly challenging if taking into account existing deficiencies in governing mechanisms along with specific concerns about climate change and adaptation processes. For instance, climate impacts do not know physical and legal borders. This implies that

adaptation governance is dealing with a broad set of actors and sectors, and as a result, it becomes fragmented. Moreover, it is hard to measure adaptation (as opposed to mitigation, which can be referred to the concentration of greenhouse gases in the atmosphere) or to clearly define its target as well as its ends (BIESBROEK 2014). Additionally, the observed evidence demonstrates heterogeneous capacities to deal with uncertainties and new conditions imposed by climate change, resulting rather in reactive adaptation actions pursuing short-term outcomes.

The study of governance in respect to adaptation decision making requires a complex analysis of actors, decisions, processes as well as formal and informal institutional mechanisms, which prompt the direction of actions (MOSER 2009). In the analysis of adaptation as a social process, interactions between various elements of complex interrelated social-ecological systems, e.g. actors, government and resource systems, and climatic exposure, form a particular model of adaptation situations allowing studying the factors that shape adaptation and its outcomes (OBERLACK and NEUMÄRKER 2013). Interactions between the elements that hamper adaptation and result in diminishing adaptive capacity are denoted in the adaptation research as barriers. Alternatively, interactions that enable adaptation and lead to the enhancement of adaptive capacity are considered as opportunities for climate change adaptation. The following subsection will introduce the concept of barriers in climate change adaptation.

2.3.1 Understanding barriers in the governance of climate change adaptation

More recurrent climatic disturbances and associated increasing losses has induced the climate-change research to shift from the focus on whether adaptation is needed to the analysis of how adaptation can occur and what impairs adaptive responses. Additionally, an increasing policy move towards adaptation action allowed analysing adaptations in practice. Because of that, more evidence on actual barriers to adaptation is now available (BIESBROEK et al. 2013). This subsection aims at providing insights to the existing general views on the conceptualization of barriers to adaptation in general and on their occurrence in the context of water governance in particular.

An increasing focus on barriers to climate change adaptation, aiming at a better understanding adaptation processes, resulted in the variety of interpretations and in a broad categorization of adaptation barriers. Many studies are very context specific,

which leads to difficulties in terms of a general conceptual understanding. In order to address this challenge current research offers a generative analysis of adaptation barriers exploring their causes and interrelations (MOSER and EKSTROM 2010, OBERLACK and EISENACK 2013). Understanding of the latter is crucial for exploring the ways to deal with barriers to adaptation (BIESBROEK et al. 2013).

Despite of the growing interest in exploring barriers, a clear interpretation as well as a definition of specific conditions or characteristics are lacking, which makes it difficult to identify barriers in actual situations. Adaptation barriers are addressed from different aspects, e.g. depending on the way adaptation is defined and along with contiguous terms, such as adaptation constraint, obstacle and limit. The IPCC sets adaptation constraints, obstacles and barriers equal, defining them as factors or processes that make adaptation planning and implementation more difficult (KLEIN et al. 2014, p.906).

Studies on adaptation barriers stress a large number of factors of various origins, which impede planning and implementation of adaptation measures (KLEIN et al. 2014). It is observed that usually impeding factors act in their entirety and not isolated, which significantly reduces an available range of adaptation options or opportunities. This can limit adaptation or even result in maladaptation (KLEIN et al. 2014). The IPCC distinguishes among knowledge, technological, physical, biological, economic, financial, human resource, social, cultural, and institutional barriers (KLEIN et al. 2014).

A broad literature on adaptation barriers provides even more categories or suggests alternative unstandardized approaches to conceptualize barriers. For instance, MOSER and EKSTROM (2010) offer a categorization of barriers based on the process of adaptation systematically distinguishing barriers for each phase of adaptation decision-making: understanding the problem, planning adaptation actions, and managing the implementation of the selected option. They observe that such aspects as leadership, resources, communication and information, and actors' values and beliefs are crosscutting recurrent barriers (MOSER and EKSTROM 2010). LEHMANN et al. (2015) reveal adaptation barriers in urban planning with the use of the analytical framework based on bounded rationality. They claim that a municipal decision maker act depending on available information on the problem, incentives to act and accessible resources. According to this argument, they point on institutional,

actor-specific, natural and socio-economic characteristics of adaptation barriers (LEHMANN et al. 2015).

Consideration of adaptation as a societal process implies focusing on individual actors or group of actors since they shape institutional environment, in which the adaptation process intends to occur. Therefore, another important aspect concerning barriers to adaptation is the fact that actors value barriers differently depending on their preferences, beliefs, and interests. In defining barriers to adaptation EISENACK and OBERLACK (2017, p.4) emphasize that "a barrier can be valued differently by different actors". For instance, the actors' perception of climate change appears for a crucial barrier. It occurs due to the lack of awareness associated with beliefs that climate change is the problem of future and does not require taking any actions at present. This impedes information use and leads to the discourse on adaptation priorities (LEHMANN et al. 2015, KIRCHHOFF et al. 2013, HILL 2013). In addition to that, barriers are often context-specific, implying that what is defined to be a barrier for one can be an opportunity for another (BURCH 2010). The perception of something being a barrier can be changed over time and along with appearance of new dimensions (BIESBROEK 2014). BIESBROEK (2014) points out on a potentially limited perception of barriers by actors, explaining this by the fact that they experience only part of a complex adaptation process. This view on barriers to adaptation is important since "what actors construct as barriers has direct consequences for the actors' response" to them (BIESBROEK 2014, p.136).

The literature reporting on adaptation barriers demonstrates that they are mostly related to institutional or social dimensions (AZHONI et al. 2017, BIESBROEK et al. 2013). Empirical evidence reveals a broad spectrum of institutional and social barriers to climate change adaptation. Due to a particular focus of the present study in water governance adaptation in river basins, a following closer consideration of such barriers will be presented in this context.

Institutions are often seen as main barriers to adaptation mainly due to their rigid nature in contrast to a required change and flexibility in adaptation. This refers to the concept of path dependence. Path dependence includes situations, in which institutions or practices "resist change because of an established and embedded focus on a specific set of issues" (MATTHEWS 2013, p. 201). It can be a severe barrier to climate adaptation, since when path dependence occurs institutions have

proven to be not able to react in a proper manner, e.g. considering new institutionalization opportunities (OBERLACK 2016). This often results in a slow, ineffective or even blocked institutional change. For instance, in the Western US water allocation policies are still based on fixed property rights with a prior appropriation rule established back in the 19th century (HAMLET 2011, KIRCHHOFF et al. 2013). This hampers flexibility of institutions in managing water in periods of climate perturbations. Existing political unwieldiness as well as high costs of establishing a new allocative system do not seem to assist the changes (HAMLET 2011). In the context of water governance, path dependence is not only associated with institutional change but also with hydrological records. In this perspective, it means that water management is based on historical records and static representations of river basin conditions as well as on short-term forecasts (GILLON et al. 2015). EISENACK and OBERLACK (2017) also reveal path dependence in established practices that often results in a stalled social learning.

The lack of coordination is also a frequent barrier, which occurs due to institutional fragmentation in a multi-level decision-making. It is likewise observed in the context of interdependencies among various actors involved, which is often the case in water governance. Under such conditions climate adaptation is impeded because of high transaction costs. One of the reasons for costs to increase can be a long-drawn decision making (OBERLACK 2017).

Another group of barriers that significantly impede the adaptation process is related to competing preferences and interests, mainly including the lack of awareness and understanding of climate change. This issue has been already highlighted above. Additionally, various interests of actors regarding water services and adaptation translating into high transaction costs may result in resistance of actors to adapt (EISENACK and OBERLACK 2017). Differences in actors' interests regarding adaptation may result in maladaptation as well by increasing vulnerability of the affected system to climate impacts (KLEIN et al. 2014).

Barriers associated with uncertainty about climate stimuli and with a limited understanding by actors of the affected system's characteristics appear to be frequently documented. This occurs due to the lack of specific local projections and/or misuse of climate knowledge in planning. A limited understanding of the system's characteristics is important for a better organization of its management and

for making predictions on the influence climate change might have on it. Finally, availability of human, financial and technological resources proves to be important to allow adaptation and to define the extensiveness of adaptation actions (EISENACK and OBERLACK 2017).

As these observations demonstrate, barriers are inherent elements of the governance process, which effect its outcomes. The influence of barriers resides in the increasing probability of failure and consequently in the reducing chances for a successful output (BIESBROEK et al. 2013).

2.4 Opportunities to climate change adaptation

The concept of adaptation opportunities is an emerging one. As demonstrated above, the adaptation research has been so far largely focused on the analysis of various adaptation strategies and their implementation as well as on how adaptation can occur. Hence, investigation of opportunities and their characteristics to facilitate adaptation is an actual and underexplored field in the climate adaptation research. This subchapter provides some existing insights on opportunities in the adaptation research. It is important to mention that opportunities to climate change adaptation do not simply represent solutions to adaptation barriers. They are considered here as an independent concept.

There is no general conceptualization of opportunities to adaptation and a common definition is lacking. The Merriam-Webster Dictionary defines opportunities as “a favorable juncture of circumstances” as well as “a good chance for advancement or progress”. In economics, the concept of opportunity is central to the entrepreneurship research, where however also little agreement on the definition and the nature of opportunities exists. There are different courses of understanding opportunities, “one contending that opportunities are discovered and another contending that they are created” (SHORT et al. 2010, p.41). Opportunities are seen as outcomes of a creative process, “whereby initial ideas are elaborated, refined, changed, or even discarded” (DIMOV 2007, p.713). Others consider opportunities as “the chance to introduce innovative (rather than imitative) goods, services, or processes” (GAGLIO 2004, p.534).

In the context of climate change, opportunities are viewed as potential positive consequences related to changing climatic conditions. Such positive gains are

primarily associated with an improved agricultural performance of some northern regions (MENDELSOHN et al. 2006), lower rates of winter mortality (EBI and MILLS 2013) as well as with benefits to some resource users or sectors. For instance, in the context of water management although changing streamflow in water systems imposes many difficulties for their management (flood control, irrigation, fishing, etc.) sometimes it can also provide benefits for their users. A guided fishing may benefit from a projected spring streamflow decrease in the watershed as high flows that occur at this period of the year challenges fishing (FARLEY et al. 2011).

Therefore, a short observation of various definitions and interpretations of opportunities results in a general understanding of opportunities as something innovative, creative and positive that increases the chances for improvement. In this vein, opportunities have indeed surfaced in the adaptation literature since quite some time already, though a unified conceptualization is still not in sight. A brief review of the adaptation literature and the case studies have highlighted four different perspectives on the concept of opportunities for adaptation. These are:

1. Opportunities as additional benefits from adaptation measures;
2. Opportunities as available (and yet unexploited) capacities to adapt;
3. Opportunities as drivers of adaptation forcing adaptive measures;
4. Opportunities as factors preventing and/or overcoming barriers to adaptation.

In the following, each of this conceptualization will be addressed individually.

2.4.1 Opportunities as additional benefits from adaptation measures

Adaptation aims at reducing risks and negative impacts resulted from climate change and variability. Besides this positive effect, adaptation to climate change can provide some other additional benefits. These beneficial effects might be both associated with changing climatic conditions or not (SMIT and PILIFOSOVA 2007). Emerging economic opportunities from climate change adaptation is an example of the co-benefits of adaptation that are not necessarily related to climate change. Businesses along with the climate adaptation frameworks tend to consider direct and indirect climate impacts on their activities and aim to develop new strategies that help to guarantee their continuity (GIZ 2012). This leads to the development of new goods and services as well as to the appearance of new business industries (biochemical, adaptive building, green energy, etc.), green jobs and

entrepreneurship, etc. (HUANG-LACHMANN and LOVETT 2016). Such opportunities are also important for businesses as being a part of their risk management strategies (GIZ 2012). Hence, adaptation may promote economic activity by creating additional benefits, especially for those who produce goods or services for adaptation needs (KLEIN et al. 2014).

Alternatively, an increased sensibility to and awareness of climate impacts may prompt adaptation measures aiming at reducing a system's vulnerability in the near future. Such short-term adaptation measures can yield supplementary benefits in terms of future reductions in vulnerability (KLEIN et al. 2014).

Finally, adaptation assists in meeting long-term sustainable objectives since adaptation and promotion of sustainable development pursue the same goals in terms of the resource access, adaptive capacity building, poverty and inequality reduction, risk management, etc. (KLEIN et al. 2014, UNITED NATIONS 2008). Sustainable adaptation aims at positively contributing to social justice and environmental conservation, reducing vulnerability of a system (ERIKSEN et al. 2011). However, as the practice shows some adaptive responses, predominantly reactive, by contrast can lead to the opposite effect. This can happen due to an excessive autonomy and flexibility in managing solutions at the lower scales of decision making. This may lead to the opposite outcomes, such as the increase in vulnerability of an affected system to climate change (HILL 2013).

Ancillary benefits of adaptation (definition according to KLEIN et al. 2014, p.910 ff) may play an important role in terms of motivating adaptation. However, KLEIN et al. (2014, p.910) identified potential impacts associated with such co-benefits of adaptation in terms of influencing a decision-making process in two ways: when considering cost-effectiveness of an adaptation option and when mainstreaming climate change adaptation into polices and practices.

2.4.2 Opportunities as available (and yet unexploited) capacities to adapt

An increased adaptive capacity largely depends on development patterns. In the context of sustainable economic development, adaptation opportunities in the form of research, education, technological innovations, accessible and improved management instruments and practices shape the initial capacity to adapt (KLEIN et al. 2014). The initial capacity to adapt can be also determined by self-motivation

and a favourable context for adaptation to happen. Therefore, this type of adaptation opportunities is characterized by a proactive move towards adaptation where the initial conditions for adaptation are favourable and result in available capacity to adapt (SHEPHERD et al. 2006). In other words, this type of opportunities emerge within the enabling environment, in which a system of concern is embedded and from which adaptation will consequently stem.

In this regard, one could hypothesize that such opportunities occur rather in developed regions or countries where progressive attitudes towards sustainable development patterns prevail and where there are capacities to comprehensively address such problems as climate change adaptation.

2.4.3 Opportunities as drivers of adaptation forcing adaptive measures

In the literature on climate adaptation, it is quite often to observe the term "drivers" being often interchangeably used with the term "opportunities". However, the closer observation allows distinguishing between "drivers" in the sense of "opportunities" from "drivers" as an independent element along with "opportunities". The former is usually related to the factors that favour adaptive processes, i.e. claimed to be a synonym to "opportunities" in this sense. These opportunities are considered in the present study as enable factors of adaptation in the function to prevent and/or overcome barriers to adaptation and will be discussed in the following subsection. The latter refers to the fact that some factors force adaptation to happen. In this sense, opportunities to climate adaptation can be considered as drivers to adaptation that are particular circumstances or events that "force the authority to make a decision about adopting the particular approach (and related procedural activities)" (SHEPHERD et al. 2006, p.39).

The logic behind attributing drivers to opportunities is that the former partly corresponds to the characteristics of opportunities. This involves that drivers emerge as an output of interactions between various elements of complex social-ecological systems. Taking adaptation measures in this context is likely to result in the reduction of vulnerability to climate change for some period. However, some factors can equally force and enable adaptation, turning up to act as both drivers and opportunities to adaptation. A clear differentiation of drivers and opportunities is an important contribution to their conceptualization.

There is enough evidence of the adaptation driven by very different factors. KRYSANOVA et al. (2010, p. 4143, ff.) in their study on the cross-comparison of various climate change adaptation strategies reveal possible drivers that are of a climatic and non-climatic nature. Among them are available financial means, extreme climate events, policies prescriptions, global development trends, etc. A policy emergence plays a significant role in adaptation to climate change by guiding adaption actions. The compliance with national or international commitments in terms of achieving sustainable development goals drives preparations for an adaptation action (HEINRICHS et al. 2009). For example, the relevance of the EU regulations (such as, in case of water governance, the EU Water Framework Directive) for the European member states is important to set off respective actions. SHEPHERD et al. (2006) also mention political or higher authority encouragement that can drive taking adaptive actions. LARSEN 2011 reports on the exposure to negative climate impacts and on the climate knowledge and familiarity with climate variability of a technical staff as major driving forces triggering adaptation.

As this short overview shows, drivers are of various nature and appear in different forms. The current study defines drivers as specific events, which lead to the increase in awareness of decision makers about climate change and its impacts and create opportunities for adaptation action (PULWARTY and MAIA 2015). These are climate extreme events, policy enactment, or appearance of a strong leader, just to name a few: “events such as droughts, which may span from seasonal to decadal and longer timescales, expose critically vulnerable conditions and, despite providing warning on potential crisis, are also opportunities for innovation.” (PULWARTY and MAIA 2015, p.286).

Though varying on their nature, drivers share some common characteristics. Adaptive responses triggered by drivers are frequently characterized as reactive. Such responses involve both taking practical actions of a physical character as well as changes in practices and decision-making processes. This is often the case of an occurrence of extreme events, e.g. a persistent drought or a severe flooding could trigger creation and implementation of a disaster response mechanism or arouse a new interest in improving management and planning practices. “It seems like an “instructive” disaster is needed to set things in motion” (KRYSANOVA et al. 2010, p. 4144). The first evidence on climate impacts usually activates actors’ awareness and

creates an opportunity space for adaptation actions (ADGER et al. 2007). However, a common observation shows that after the adaptation action driven by an extreme event was taken, the perception of climate change declined over time along with the intention of actors to adapt (CHRISTOPLOS 2006, KIRCHHOFF et al. 2013). In this regard, adaptation can be rather considered as a short-term, with a low potential to comprehensively correspond to contextual factors and the system's dynamics. Fast reactive responses may equally result in the increasing vulnerability of the affected system and even in degradation of its ecological component (ERIKSEN et al. 2011, HILL 2013). Concerning adaptive capacity, drivers of adaptation mainly refer to the enhancement of a coping ability. The reason for this is that the intention to make decisions in favour of a comprehensive adaptation is often gradually calling off over time.

Many driving factors are crosscutting both forcing and enabling adaptation. For instance, the issue of leadership is often mentioned in the literature as one of the important factors for initiating and favouring adaptation actions (RENDÓN and GEBHARDT 2016, PULWARTY and MAIA 2015, EISENACK et al. 2014, SHEPHERD et al. 2006). Following the logic, the appearance of a leader can be considered as an event (similar to the occurrence of an extreme event), and therefore appears as a driver to climate adaptation. The leader's further adaptation associated actions often refer to the change in institutional settings that enable adaptation, and therefore leadership appears as an enabling factor. The same holds for policies, their appearance serves as a push towards an action, while consequent initiated actions in meeting policy requirements can enable the adaptation process.

Correspondingly, while the adaptation process is advancing, it is less driven by the driving factors but rather by the factors that enable or facilitate the adaptation process (RENDÓN and GEBHARDT 2016). This implies that drivers by pushing adaptation are generally related to a pre-adaptation phase, when along the process a transformation occurs, and there are facilitating factors that take over this role and enable adaptation to happen. This is an important reasoning for differentiating adaptation opportunities as drivers from opportunities as enabling factors. In this context, adaptation characteristics will also differ in that along the process a move towards a more comprehensive and longer-term adaptation should happen more distinctly.

Understanding of drivers is important for designing adaptation strategies in the sense that human-related factors could be then steered and if necessary modified (KRYSANOVA et al. 2010). It can be also helpful to better understand climate-induced drivers in order to detect the causal effects of adaptation actions.

2.4.4 Opportunities as factors preventing and/or overcoming barriers to adaptation

Finally and most frequently, adaptation opportunities are considered as factors preventing and/or overcoming barriers to climate change adaptation. To this end, the IPCC defines adaptation opportunities as "enabling factors that enhance the potential for actors to plan and implement actions to achieve their adaptation objective(s) or facilitate adaptive responses by natural systems to climate risk" (KLEIN et al. 2014, p.908-909). The definition outlines the scope of opportunities, which in contrast to the drivers of adaptation refer to different stages of the adaptation process, comprising planning as well. Though some empirical evidence shows that overcoming barriers can clearly occur in the advanced stages of adaptation and are particularly associated with actor-related aspects and knowledge on climate change adaptation (RENDÓN and GEBHARDT 2016), consideration of the planning aspect is important for supporting a proactive, anticipatory adaptation. Planned longer-term adaptive responses are hence at the focus of this group of opportunities. In this context, it is important to differentiate opportunities as enabling factors from all kinds of adaptation options and means that may also assure a long-term adaptation. Opportunities represent intervention mechanisms, including changes in practices and decision-making processes that expand adaptation options.

As it follows from the definition, there is a two-way relationship between opportunities and actors. Opportunities are initiated by actors and opportunities enlarge the ability of actors to pursue their adaptation goal. The literature review of the studies reporting on various ways of overcoming barriers to adaptation demonstrates that the range of such "opportunities" is relatively broad. Awareness rising and an effort to increase education on climate change and its impacts are claimed to be important to overcome social barriers to adaptation (JONES 2010). Numerous studies consider mainstreaming of climate adaptation, i.e. integration of climate change vulnerabilities or adaptation into planning processes or existing policies, as an important opportunity for innovations and for awareness raising about

climate impacts (UITTENBROEK et al. 2013, AGRAWALA 2005). Mainstreaming consequently relates to the aspects of scientific information production and use. In this view, information provision by state authorities, linking scientific information with a decision making, engaging the public, creation of specific dedicated departments that produce climate knowledge and disseminate it, are quite often observed as propositions to enable information uptake and flow (LEHMANN et al. 2015, MOSER et al. 2008, HEINRICHS et al. 2009).

Another way to overcome barriers are associated with availability of the resources (technological, financial, human, etc.) required for adaptation and with an improving equitable access to them or to various risk-spreading mechanisms (HEINRICHS et al. 2009, MOSER et al. 2008). Combining climate adaptation with other public concerns that strengthen social and human capitals is also argued to enable the adaptation process (JONES 2010).

At most, opportunities refer to institutional settings that play a key role in governance of adaptation. There is a wide range of studies reporting on enabling institutional environments that aim at supporting adaptation. In that regard, the role of institutions in achieving efficient adaptation is argued to be important in several ways (GIZ 2013): first, institutions are the main determinants of the available capacity of a system of concern to successfully adapt to climate change and variability; institutions and their capacities are crucial for a planned adaptation and its feasibility; and finally, institutions are central for fostering cooperation to support climate adaptation. In this context, the research on adaptation identifies multiples opportunities for adaptation governance that include participatory approaches, expanding coordination and collaboration across administrative levels, establishment of institutions to promote learning among stakeholders, clear assignment of responsibilities, increasing institutional flexibility and fit, supporting social learning (GIZ 2013, EISENACK et al. 2014, RENDÓN and GEBHARDT 2016, MOSER et al. 2008). These opportunities associated with the role of institutions in governing adaptation are defined as “conditions and strategies that enable actors to prevent, alleviate or overcome a specific institutional trap or trade-off” OBERLACK (2017, p.814).

The review demonstrates a broad range of factors that may support adaptation. Since the focus on opportunities in the adaptation research is relatively recent, there

is no general agreement on their classification. Bringing together the existing literature in the Intergovernmental Panel on Climate Change (IPCC) report, KLEIN et al. (2014) aggregate factors that support climate adaptation, e.g. raising awareness, building and increasing human and institutional capacity, using various assessment tools or policy potentials, learning and knowledge management, and technological innovation.

As the review shows, there are different aspects of adaptation barriers that stir the emergence of opportunities to adapt. It is important to mention that opportunities' relation to barriers is already an important distinguishing characteristic of opportunities as enabling factors, for example, from those acting as drivers. Some studies assign the occurrence of climate extreme events to the opportunities in the sense of being able to overcome barriers. Although subsequently initiated adaptive actions may help to alleviate barriers to adaptation, this is not their initial intention. Extreme events drive adaptive responses, implementation of which may reveal some barriers in the process, but extreme events are not an opportunity in the sense of overcoming adaptation barriers.

The review also confirmed that studies usually conclude with some short suggestions on how to deal with adaptation barriers, focusing their analysis on the latter. Many recommendations include options, strategies and ways to deal with barriers but not all can be attributed to the "opportunities". "Many of the suggestions are not made to actually intervene in a faltering process, but to improve future governance of adaptation and prevent barriers from re-appearing" (BIESBROEK et al. 2013, p. 1125). A systematic review and analysis of the selected cases studies intends to provide more insight on this issue.

2.5 Chapter summary

The chapter starts with the overview on climate change adaptation generally defining it as adjustments to climatic stimuli and their impacts. Climate change adaptation does not simply result in finding a right technical solution to adapt the affected resources. It is a social process, which includes multiple interactions within various elements of an effected system that need to be coordinated. In this regard, the present study analyses adaptation as a governance issue in the context of water management in river basins.

Focusing on adaptation in the water sector is insightful for the analysis of opportunities since much research work had been conducted with regard to water management and governance to draw on. Water governance is likewise particularly promising for studying adaptation opportunities because they are expected to be revealed due to the growing evidence of existing barriers. The reviewed findings on adaptation opportunities from other studies are presented in a new aggregated perspective. It demonstrates that understanding of opportunities goes far beyond their classic interpretation in the adaptation literature as solutions to barriers.

Opportunities to climate change adaptation in their various forms have been surfaced in the adaptation literature since already some time. However, there is still a necessity to clearly define these different manifestations of adaptation opportunities, contributing to their conceptualization. Based on the general initial understanding of opportunities as favourable factors or circumstances that determine progress or advancement, the present study distinguishes between four types of adaptation opportunities (Figure 1).

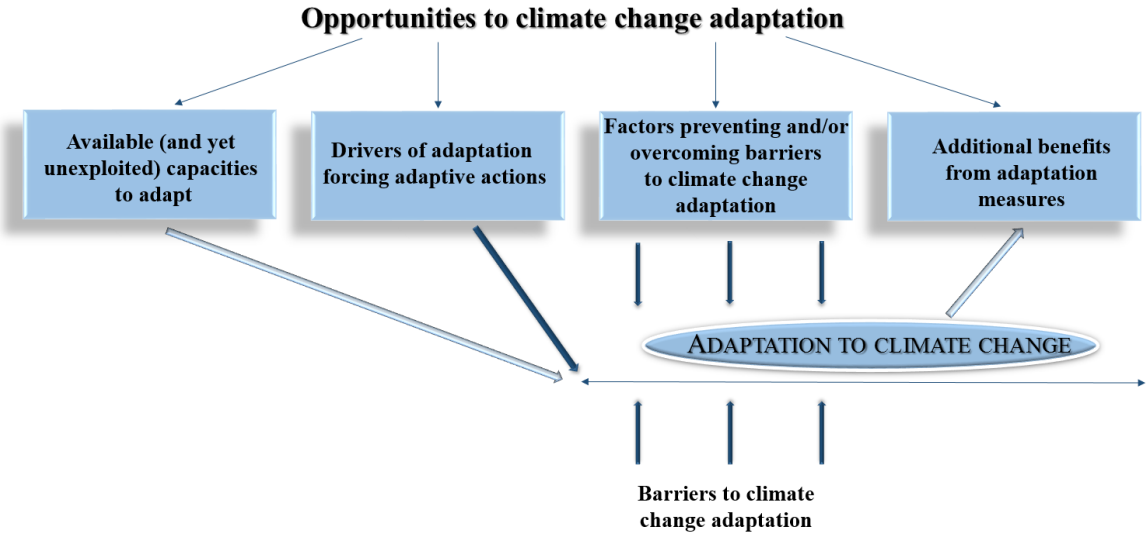

Figure 1. Different perspectives on the concept of opportunities to climate change adaptation.

On the one hand, opportunities to climate change adaptation can be viewed as available (and yet unexploited) capacities to adapt, i.e. advantageous conditions for adaptation to occur that emerge in the enabling environment, in which a system of concern is embedded. These conditions determine the initial capacity to deal with climate variability and change. Such opportunities appear at the pre-adaptation

stage, “naturally” triggering adaptation to occur. On the other hand, adaptation opportunities are additional benefits that the adaptation process engenders, e.g. economic and social opportunities or opportunities in terms of future reductions in a system’s vulnerability.

Additionally, opportunities are often seen as drivers or enabling factors to adaptation. These types of opportunities create a major confusion as being often interchangeably used. This can be explained by the fact that both are sets of interacting factors and conditions within complex affected systems, which force or enable adaptation and lead to a temporary or the overall enhancement of adaptive capacity. From this perspective, drivers are particular circumstances or events that force responsive activities in the face of climate shocks, creating an opportunity space for adaptation to occur. In this regard, similarly to opportunities as available capacities drivers are generally related to the pre-adaptation phase, triggering adaptive measures. However, in contrast to opportunities as available capacities that appear to support proactive adaptation, drivers prompt reactive responses to climate variability and change, which implies that there is an actual necessity to deal with climate impacts.

Opportunities in the function of enabling factors are separately or instantaneously operating factors and strategies that enable adaptation to climate change in terms of preventing and/or overcoming barriers to climate adaptation. These opportunities are directly attributed to the process of adaptation and aim at enabling it across all its stages.

3 Methods

3.1 Introduction

This chapter presents the methods and procedures used to conduct the study. Since adaptation opportunities are poorly examined, the study is designed as exploratory. Exploratory research appears as the most relevant for defining new concepts in that it involves gaining knowledgeable insights on the examined issue and development of new ideas and assumptions. This is certainly helpful to create a comprehensive picture of adaptation opportunities, which facilitates their theoretical conceptualization.

The chapter begins with an overview on the systematic literature review method and its application for studies on climate adaptation in general and for the present study in particular. Further, the chapter gives insights on the data selection and provides information on the selected case studies by regions and river basins. The description of the coding procedure explains how the data has been processed. A developed codebook with interpretation of codes used for the systematic analysis of the case studies is presented next. Finally, the way the data was analysed is explained.

3.2 Systematic literature review method

To explore opportunities to climate change adaptation a systematic literature review method is used. A systematic review is a scientific tool that allows for synthesis of a wide range of studies in a specific research field. This method originates from health sciences, wherein it initially aimed at providing evidence of effectiveness of healthcare interventions by summarizing and aggregating the obtained results. At present, this method is widely used in other sciences, including environmental sciences and particularly adaptation research.

The systematic review is “a method of critically appraising, summarizing, and attempting to reconcile the evidence on a particular problem” (PETTICREW and ROBERTS 2008, p.198). The method is largely used for knowledge generation in that it contributes to integration and expansion of research evidence. It can be also used to support decision making, if the objective involves investigation of a particular decision within a specific context (PETTICREW and ROBERTS 2008). For the purpose of the present study, the use of the systematic review method is mainly designed to

contribute to enhancement of research evidence on opportunities to climate change adaptation.

The systematic review has potential to fulfil various functions that are important for knowledge extension. First, it accomplishes a function of stocktaking, implying the exact systematization and further categorization of what has been done formerly (PETTICREW and ROBERTS 2008). This helps to define research gaps and to plan new studies. For instance, while exploring adaptation opportunities, which are poorly examined in the climate adaptation field, the systematic review is key to emphasize the existing knowledge and to guide future research by prioritizing focus areas. By gathering the empirical evidence, systematic reviews provide a basis for assessment of present policies or practices (PETTICREW and ROBERTS 2008).

A systematic review process involves several steps to follow for the selection and evaluation of literature. First, one should formulate a concrete research objective and determine the scope of the study (BERRANG-FORD et al. 2015). Second, by the document selection it is important to clearly set criteria that assist the sorting out of multiple documents. These criteria should also include those on studies' quality. Finally, after having selected a sample of appropriate studies, one proceeds with their analysis by synthesizing evidence (BERRANG-FORD et al. 2015, FORD et al. 2011). An advantage of this method after all is that the obtained results could be re-examined on their reliability.

However, apart from diverse positive sides of this methodological tool, systematic reviews are likewise criticised. The criticism mainly refers to the limitations in provision of practical suggestions how to deal with researched problems (PETTICREW 2015). In this regard, many proponents of this method claim that systematic reviews should give more attention to integration of contextual specificities and address the aspects of implementation (PETTICREW 2015, PETTICREW and ROBERTS 2008).

In respect to climate change adaptation, the systematic review is an important tool since the concept of climate adaptation is developing rapidly and there is a need for "comprehensive syntheses of existing research and tools to evaluate progress on adaptation" (BERRANG-FORD et al. 2015, p. 756). A particular advantage of this

method for the adaptation research involves transparency while keeping track of adaptation actions.

The systematic review does not solely allow for generic observations but also gives room for the analysis in different contexts and settings (BERRANG-FORD et al. 2015). Therefore, for the present study it can be relevant in terms of the analysis of a contradictory evidence, for example, by examining why under certain conditions opportunities function as enabling factors while under another they fail.

Finally, this approach has a high potential for adaptation research by using various units of analysis apart from single studies, e.g. focal events, specific adaptation actions, etc. (BERRANG-FORD et al. 2015). In this perspective, the present study uses models as a particular unit of analysis that capture interactions between various elements of complex social-ecological systems, e.g. actors, government and resource systems, and climatic exposure. This allows directly studying factors that shape adaptation and its outcomes.

For the purposes of the present study, i.e. improving understanding of opportunities to climate change adaptation, a systematic qualitative analysis of the literature is meant to exercise a stocktaking function. This includes delineation and generation of the existing knowledge and evidence necessary for conceptualization of opportunities. This provides a basis for a further subsequent synthesis of evidence following on from the analysis of the models. However, this can be problematic in that adaptation research involves various traditions and approaches in understanding and interpretation of climate change adaptation. In that regard, BERRANG-FORD et al. (2015) suggest looking for the literature that contains concurrence regarding the designed research objective. A particular attention should be paid on the extraction of information as well as on the evaluation of its quality and relevance for the research purposes.

3.3 Data selection

The selection of primary case studies for the purposes of the thesis is based on the research of EISENACK and OBERLACK (2017) on adaptation barriers in water governance of river basins. This allows for examination of opportunities in the context of the same adaptation situations and with the reference to already identified adaptation barriers. The studies were retrieved from the databases of Web of

Science (WoS) and Scopus so that the research is based on primary data and the articles are peer-reviewed. The inclusion criteria of these studies also involve the analysis of intentional climate change adaptation options as well as the examination of collective decision making and barriers to climate adaptation (EISENACK and OBERLACK 2017). The final sample included 26 selected primary studies on water governance adaptation in river basins worldwide from 20 scientific journals for the period of 1990-2015 (Table 1).

Country	River basin	Reference
USA	Watersheds in Washington State	Binder; L. C. W. (2006): Climate change and watershed planning in Washington state. Journal of the American Water Resources Association, 42, 915–926.
	McKenzie River	Farley; K.A., Tague; C., Grant; G.E. (2011): Vulnerability of water supply from the Oregon Cascades to changing climate: Linking science to users and policy. Global Environmental Change, 21, 110–122.
	Yahara River	Gillon; S., Booth; E.G., Rissman; A.R. (2015): Shifting drivers and static baselines in environmental governance: Challenges for improving and proving water quality outcomes. Regional Environmental Change, 16, 759–775.
	Columbia River	Hamlet; A.F. (2011): Assessing water resources adaptive capacity to climate change impacts in the Pacific Northwest Region of North America. Hydrology and Earth System Sciences, 15, 1427–1443.
	Susquehanna River	O'Connor; R.E., Yarnal; B., Neff; R., Bord; R., Wiefek; N., Reenock; C., Shudak; R., Jocoy; C. L., Pascals; P., Knight; C.G. (1999): Weather and climate extremes, climate change, and planning: Views of Community Water System Managers in Pennsylvania's Susquehanna River Basin. Journal of the American Water Resources Association, 35, 1411–1419.
	Bear river basin	Welsh; L.W., Endter-Wada; J., Downard; R., Kettenring; K.M. (2013): Developing adaptive capacity to droughts: The rationality of locality. Ecology and Society, 18, 7.

Country	River basin	Reference
Brazil, USA	Jaguaribe-Banabuiu Basin, Itajai Basin (Brazil) Watersheds in Arizona and Georgia (USA)	Kirchhoff; C.J., Lemos; M.C., Engle; N.L. (2013): What influences climate information use in water management?: The role of boundary organizations and governance regimes in Brazil and the U.S. Environmental Science & Policy, 26, 6–18.
Mexico, USA	Colorado River	Pulwarty; R.S. and Melis; T.S. (2001): Climate extremes and adaptive management on the Colorado River: Lessons from the 1997–1998 ENSO event. Journal of Environmental Management, 63, 307–324.
	Arizona-Sonora region	Wilder; M., Scott; C.A., Pablos; N.P., Varady; R.G., Garfin; G.M., McEvoy; J. (2010): Adapting across boundaries: climate change, social learning, and resilience in the U.S.–Mexico border region. Annals of the Association of American Geographers, 100,917–928.
Mexico, Portugal, Spain, USA	Colorado River (Mexico/USA) Guadiana River (Portugal/Spain)	Pulwarty; R.S. and Maia; R. (2015): Adaptation Challenges in Complex Rivers Around the World: The Guadiana and the Colorado Basins. Water Resources Management, 29, 273–293.
Canada	Southern Saskatchewan	Hurlbert; M., Diaz; H., Corkal; D.R., Warren; J. (2009): Climate change and water governance in Saskatchewan, Canada. International Journal of Climate Change Strategies and Management, 1, 118–132.
	Okanagan	Shepherd; P., Tansey; J., Dowlatabadi; H. (2006): Context Matters: What Shapes Adaptation to Water Stress in the Okanagan? Climatic Change, 78, 31–62.
Canada, USA	Columbia River	Cosens; B.A. and Williams; M.K. (2012): Resilience and Water Governance: Adaptive Governance in the Columbia River Basin. Ecology and Society, 17, 3.
Canada, Chile	Southern Saskatchewan (Canada) Elqui (Chile)	Hurlbert; M.A. and Diaz; H. (2013): Water Governance in Chile and Canada: A Comparison of Adaptive Characteristics. Ecology and Society, 18, 61-83.

Country	River basin	Reference
Argentina, Canada	Mendoza (Argentina) Oldman River (Canada)	Hurlbert; M.A., Montana; E. (2015): Dimensions of Adaptive Water Governance and Drought in Argentina and Canada. Journal of Sustainable Development, 8, 120-137.
Brazil	18 river basins	Engle; N.L. and Lemos; M.C. (2010): Unpacking governance: Building adaptive capacity to climate change of river basins in Brazil. Global Environmental Change, 20, 4-13.
Chile	Aconcagua River	Hill-Clarvis; M. and Allan; A. (2014): Adaptive capacity in a Chilean context: A questionable model for Latin America. Environmental Science & Policy, 43, 78–90.
Chile, Switzerland	Aconcagua (Chile) Rhone (CH)	Hill; M. (2013): Adaptive Capacity of Water Governance: Cases From the Alps and the Andes. Mountain Research and Development, 33, 248–259.
Portugal, Spain	Guadiana River	Cots; F., Tàbara; J.D., McEvoy; D., Werners; S., Roca; E. (2009): Cross-Border Organisations as an Adaptive Water Management Response to Climate Change: The Case of the Guadiana River Basin. Environment and Planning C, 27, 876–893.
Denmark	Multiple rivers	Larsen; S.V. (2011): Risk as a challenge in practice: Investigating climate change in water management. Regional Environmental Change, 11, 111–122.
Botswana, Lesotho, Namibia, South Africa	Orange-Senqu River	Kistin; E.J. and Ashton; P.J. (2008): Adapting to Change in Transboundary Rivers: An Analysis of Treaty Flexibility on the Orange-Senqu River Basin. International Journal of Water Resources Development, 24, 385–400.
Australia	Catchments in northeast Queensland	Boer; H. (2010): Policy options for, and constraints on, effective adaptation for rivers and wetlands in northeast Queensland. Australasian Journal of Environmental Management, 17, 154–164.

Country	River basin	Reference
Australia	Murray-Darling Basin	Pittock; J. and Finlayson; C.M. (2013): Climate change adaptation in the Murray-Darling Basin: Reducing resilience of wetlands with engineering. Australian Journal of Water Resources, 12, 161-169.
		Wei; Y., Langford; J., Willett; I.R., Barlow; S., Lyle; C. (2011): Is irrigated agriculture in the Murray Darling Basin well prepared to deal with reductions in water availability? Global Environmental Change, 21, 906–916.
	Tweed River	Singh-Peterson; L., Serrao-Neumann; S., Crick; F., Sporne; I. (2013): Planning for climate change across borders: Insights from the Gold Coast (QLD) – Tweed (NSW) region. Australian Planner, 50, 148–156.
Multiple	Elbe, Guadiana, Rhine, Nile, Orange, Amudarya	Krysanova; V., Dickens; C., Timmerman; J., Varela-Ortega; C., Schlüter; M., Roest; K., Huntjens; P., Jaspers; F., Buiteveld; H., Moreno; E., Pedraza Carrera; J. de, Slámová; R., Martínková; M., Blanco; I., Esteve; P., Pringle; K., Pahl-Wostl; C., Kabat; P. (2010): Cross-Comparison of Climate Change Adaptation Strategies Across Large River Basins in Europe, Africa and Asia. Water Resources Management, 24, 4121–4160.

Table 1. Primary case studies, regions and river basins.

3.4 Coding

To identify interactions between various elements of adaptation actions coding methodology was used. Coding is a practical tool that is widely used for a qualitative analysis as it helps to systematically organize textual data. Coding allows subdividing and categorizing the analysed data by revealing commonalities, patterns and differences (BASIT 2003). In this regard, the process of coding involves "relating text passages to categories that the researcher had either previously developed or which he or she develops ad hoc" (KELLE 1997, p.6). Creation of categories promotes development of a conceptual scheme that guides the research and helps to compare across data, build a hierarchy of categories, modify and re-examine them (BASIT 2003). Therefore, coding is not the analysis itself, but a process that anticipates the analysis.

The categories that are assigned to the text's fragments are called codes. Codes are "tags or labels for allocating units of meaning to the descriptive or inferential information" (BASIT 2003, p. 144). Development of codes for the present study on adaptation opportunities was based on OSTROM's (2009) Social-Ecological Systems (SES) framework and on its modification for the climate adaptation context by EISENACK and OBERLACK (2017).

The SES framework helps to explain outcomes (O) at the SES level, which result from interactions (I) in action situations framed by main elements of complex SES: resource systems (RS), resource units (RU), actors (A) and governance systems (GS) (OSTROM 2009). These elements or subsystems function within broader social-political-economic settings (S) and in the context of related ecological systems (ECO) (OSTROM 2009). The modification of the framework for the climate adaptation context involves introduction of additional category "adaptation option" (AO) to characterize adaptation examined in a primary study (EISENACK and OBERLACK (2017). These main elements represent first-tier categories in the SES framework.

Additional codes were introduced to cover the scope of the study in terms of exploring driving factors that force adaptation (DR) and in terms of revealing the way opportunities correlate with adaptation barriers (BR). More detailed codes that include explanatory factors form second- and third-tier attributes of the adjusted SES framework.

Coding of the data from primary case studies was processed electronically using the software MaxQDA. The segments of the case studies that proved to include explanatory factors form second- and third-tier attributes of the adjusted SES framework, using at least one interaction attribute (I) and at least one RS-, A-, GS-, S- or AO-attribute, were systematically coded. Each such statement is considered as a model. Models encapsulate the results of interactions documented in primary studies and serve as units of analysis. Within the same case study, similar constellations of factors can be repeated more than once. In this case, there is no extra differentiation between models, meaning that the same constellation of factors across one study was coded as one model. The coding procedure was repeated twice. If the codes were changed while coding a new study, the already coded studies were re-examined, and if necessary were subjected to the coding procedure

again. In this way, through a stepwise coding, a detailed codebook was inductively developed and refined on a continuous basis (Table 2). In the final round, all models were checked for the codes congruence with a final codebook. This translated to a data set of 87 models (with a range of 1-12 models per study) and 107 attributes that hold for them.

Code		Interpretation
Outcome		
O1	Opportunity to adaptation is reported.	The case study reports and explains an opportunity to climate change adaptation.
Driving factors		
DR1	Extreme events	Occurrence of extreme events triggers adaptation action.
DR2	Leadership	Appearance of a strongly committed and active actor/group of actors at the management or administrative level that promotes adaptation.
DR3	Political/higher authority encouragement	There is a pro-conservation government/initiative that encourages adaptation related actions.
DR4	Compliance with (inter)national commitments	Emergence of national and international policies for climate change adaptation triggers adaptation.
DR5	Other drivers	Health issues, development processes and other kinds of pressures that may also drive adaptation actions.
DR6	Capacity to adapt	Initially available capacity of operators to adapt.
Decision-making		
D1	Enhancing climate information use	Enhancing the usage of climate relevant information in planning and management practices, necessary for responding to longer-term changes (intra-annual variability, evaluation of data on extremes and mean values, climate projections).
D11	Recognition of climate impacts	Actors are aware of or have perception to be exposed to climate impacts.
D12	Consideration of climate change	Discussions about climate change and investigations on its impacts.
D13	Inclusion of climate information	Direct treatment of climate information in management or planning processes.
D14	Research on climate impacts	Detailed or further research on climate change impacts.
D2	Adjusting government	Changes in government regulations or

	regulations	institutional design.
D21	Strengthening government regulations and incentives	There is a need for stronger regulations and incentives.
D22	Creating new government regulations or arrangements	Creation of new government settings in case of inconsistent integration of climate adaptation into policies and planning frameworks.
D23	Changing government regulations	Changes in current governing patterns in order to improve resource use in the setting of climate disturbances.
D3	Integration	Integrating various aspects (social, economic, climate, political, etc.) as well as all actors involved at different levels to prepare responsive actions to climate change adaptation.
D4	Learning	There are various social learning processes that helps to address climate adaptation needs.
D5	Collaboration and coordination	
D51	Coordination with beneficial effects	Coordination of actors and/or agencies is mainly accompanied by information and resource flows.
D52	Research networks and knowledge partnerships	Collaboration of actors on knowledge and climate information production.
D52	Scientists-stakeholders collaboration	Particular type of knowledge partnerships that involves boundary interactions between scientists and stakeholders on information provision and uptake.
D6	Capacity building	Provision of information, water accounting and necessary resources either from government or other institutions in order to favour adaptation.
Actors		
A1	Individual knowledge	
A11	Understanding climate stimulus	Actors understand how climate change may affect the resource system.
A12	Understanding SES	Actors have a good understanding of the system they operate in.
A13	Understanding interdependencies in a SES	Actors have a good understanding of interdependent elements of the system they operate in.
A14	Awareness of climate change impacts	Actors are aware about climate impacts or they have a perception to be exposed to climate them.

A2	Homogenous beliefs, interests and priorities	
A21	Homogeneous beliefs	Actors have homogeneous beliefs about climate change and its impacts.
A22	Interest in climate change	Interest in climate change of individual actors who perceive the vulnerability of the resource system towards climate impacts.
A23	Trust building among actors	All actors are pursuing cooperative strategies and common interests.
A24	Political (public) acceptability	Adaptation related actions do not conflict with political values.
A3	Access to material resources	Actors possess resources necessary for the adaptation process.
A31	Available financing	Actors have access to funding means.
A32	Increasing technical capacity	Actors are able to increase technical capacity to prepare adaptive responses to climate impacts.
A4	Access to information resources	
A41	Use of modelling tools	The use of modelling tools for predictions and analysis of climate impacts.
A42	Available data on climate change projections at the local scale	There is available data on climate change projections at the local scale.
A43	Information on the system and on climate events	The use of information on the system actors are operating in and on local climate events in decision-making.
A44	Provision and use of new/additional information	The use of new, updated/additional information on climate and/or climate impacts in decision-making.
A45	Use of information on past events	The use of information on past climate extreme events.
A46	Communication of information	Dissemination of relevant climate information and demonstration of climate impacts to managers in order to increase awareness about climate change.
A5	Staff resources	
A51	High professional staff	Professional managers show familiarity with climate variability and change, helping to bring climate impacts into decision-making process.
Resource system		
RS1	Size and scale of a resource system	

RS11	A resource system is embedded in a larger water system	The examined resource system is a part of a larger system, which is relevant for analysis.
RS12	Upstream-downstream effects	A particular positioning of actors of the resource system that has implications for decision-making.
RS2	Stimuli and exposure	
RS21	Current climate stimuli	Current climate stimuli that affect the resource system.
RS211	Drought	
RS212	Flood	
RS213	High variability	
RS214	Low variability	
RS215	Other	
RS22	Climate stimuli not (yet) experienced	Expected climate stimuli in view of climate change.
RS221	Flood	
RS222	Drought	
RS223	Other	
RS3	Current state of a resource system	
RS31	Degradation of a system	The examined resource system is in a degraded condition.
RS32	Water pollution	
RS4	Concurrent stimuli	The resource system is affected by a concurrent stimulus, e.g. development processes, population growth, etc.
Governance system		
GS1	Scale of institutions	Temporal boundaries of institutional operation
GS11	Continuity in formal capacity	Continuity in formal capacity after the planning process has been completed.
GS2	Adaptiveness of institutions	The extent to which institutions are able to be changed.
GS21	Flexibility of institutions	Flexibility in procedures for institutional change.
GS22	Complex management system	Management or governance system is considered complex due to many actors involved in managing process.
GS3	Social connectivity	Characteristics of institutionalised procedures (i.e. chains of actions, events and outcomes) and networks (i.e. connections between multiple positions and actors) that connect actors within and across tiers of social

		organisation.
GS31	Vertical coordination	Coordination between actors of the analysed resource system and other governance levels.
GS32	Horizontal coordination	Coordination between different departments of the same-level public organizations.
GS321	Coordination of data and knowledge	Coordination between actors/ different departments of public organizations at the same-level of decision-making for data and knowledge exchange.
GS322	Common efforts and resources	Coordination between actors/ different departments of public organizations at the same-level of decision-making for joint efforts and resources.
GS33	Top-down decision-making	Decision-making process is based on a hierarchical, top-down manner.
GS34	Decentralized governance system	The governance system is characterized as decentralized.
GS4	Rights and responsibilities	
GS41	Institutional incentives and priorities	
GS411	Long-term focus	Operational rules prompt long-term planning.
GS 412	Efficiency and conservation are included/prioritized	Adaptive needs of ecosystems are prioritised.
GS413	Rules based on historical hydrology	Operational rules are based on historic hydrologic conditions.
GS42	Responsibilities	Attributes of position and choice rules that regulate the positions of participants and their actions associated to these positions.
GS421	Clear not-fragmented responsibilities/decision-making	Responsibilities are clear.
GS422	Fragmented responsibilities	There are multiple independent actors of decision-making that are not coordinated.
GS43	Property rights	
GS431	Secure property rights	Security of property rights is high.
GS431a	Secure property rights with fixed allocations	Security of property rights is high and they provide their holders with the right to a fixed amount of a resource (e.g. prior appropriation rule).
GS5	Actors	
GS51	Stakeholder participation	Eligibility of stakeholders to participate in decision-making.
GS52	Leadership	There is a strong leader in a stakeholder group that can influence decision-making process.
GS6	Social learning	Institutional attributes that shape how

		information, knowledge, values and preferences are constructed, communicated and accepted among participants.
GS61	Effective science-policy/science-management interface	The science-policy/science-management interface is effective in terms of social learning.
GS62	Institutional learning	Effective institutional learning, incl. learning process as a result of information and knowledge flow across all levels of government.
GS63	Learning from other examples	Learning from other examples or areas takes place.
GS64	Context specific	Social learning is based on the understanding of interdependencies of actors in SES.
GS65	Learning is based on past experiences	Learning is based on past experiences with climate variability.
GS66	Education of stakeholders	Communication with and education of stakeholders (and public).
GS9	Control	Type of control over the system's management and over the aggregate outcomes of an adaptation situation.
GS91	Centralized coordinated	Distribution of power and authority is well-coordinated under a hierarchical governance mode.
GS92	Polycentric	Distribution of power and authority among various well-coordinated centres.
Adaptation options		
AO1	Reactive adaptation	
AO2	Adaptation responses complementary with	Adaptation responses are complementary with various management and planning acts/programs.
AO21	Nature conservation and management acts	
AO22	State planning/management acts	
AO23	Water allocation management	
AO24	Water conservation program	
AO25	Water agreements	
AO26	Adaptive management program	
AO3	Formation of institutional bodies	Adaptation requires formation of various types of institutional bodies for its planning and implementation.

AO31	Local watershed units	
AO32	Joint institutions	Transboundary institutional arrangements.
AO33	Basin-based councils	
AO34	Interface organisations	Organizations that function as information brokers.
Congruence to a barrier		
BR	Congruent to a specific barrier	Opportunity is related to a specific barrier in the adaptation process.

Table 2. Codebook

3.5 Data analysis

The coded models were subsequently analysed since different sets of identified models contain different aspects of the examined issue. Some ideas about organizing the observed aspects into broad clusters of adaptation opportunities have already emerged from the first reading of the data (they were systematically presented in the subchapter 2.4). Final clusters evolved from the analysis of the identified models. Their creation was mainly based on the meaning embedded in the models. Clusters tagging occurred through the refinement of the meanings in the models. This helped to compare data, generalize, and identify patterns and differences.

Clusters were then consistently analysed qualitatively one by one. In this way, a data analysis allowed for extracting necessary explanatory factors to characterize adaptation opportunities. This translated into inductive identification of characteristics attributed to the revealed types of adaptation opportunities. In case of opportunities as factors preventing and/or overcoming barriers the data analysis allowed for revealing recurrent factor constellations due to their extended presence in the case studies. They are presented in the tables with the results in the subchapter 4.2.

3.6 Chapter summary

An exploratory nature of the study aims at gaining valuable insights to extend and to contribute to the appearing concept on opportunities in the adaptation research. The systematic review of case studies on water governance adaptation in river basins worldwide appears to inductively shape a certainly better understanding of adaptation opportunities and their relation to adaptation decision making. The coding procedure helped to capture models that include constellations of explanatory factors important for characterizing adaptation opportunities. Finally,

the identified clusters of opportunities were systematically and, to the extent it was possible, context-independently analysed.

4 Results

4.1 Introduction

The chapter presents the main results of the study. It first reports on the general results in accordance with the presented categorization of adaptation opportunities defined in the chapter 2.4. It continues with the focus on the most observed categories: opportunities as drivers forcing adaptive measures and opportunities as factors preventing and/or overcoming barriers to adaptation. It systematically addresses the most important findings for these categories. The results are introduced with the use of graphs, tables and the thematic content analysis.

4.2 General results

The analysis of the extracted models that reflect adaptation situations by capturing interactions between the coded elements of complex SES, e.g. climatic stimuli, actors, government and resource systems, to a different extent allowed examining all types of opportunities with the exception of opportunities as additional benefits from adaptation measures (Figure 2). This can be explained by the fact that additional benefits of adaptation in its literal sense, i.e. independent from their benefits in terms of future reductions in vulnerability, occur rather at the advanced stages of adaptation that were not at the focus of the analysed case studies.

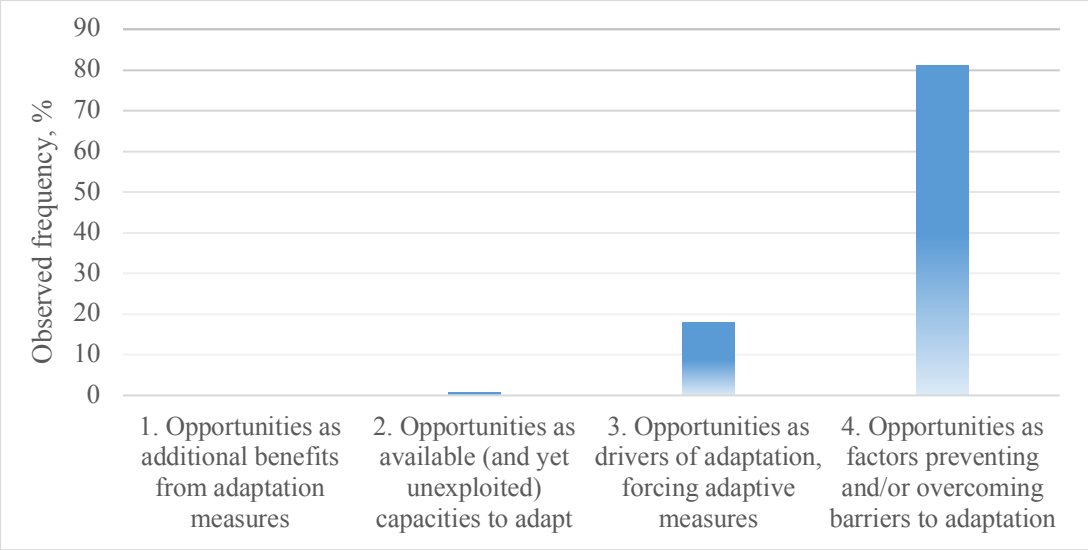

Figure 2. Opportunities for climate change adaptation: frequency of observation.

Opportunities as available (and yet unexploited) capacities to adapt are poorly represented, most likely due to a currently prevailing reactive nature of adaptation. However, an initiative move towards adaptation was observed. The study of

SHEPHERD et al. (2006) on adaptation to the water stress in the Okanagan region in Canada shows an example of a self-induced and proactive adaptation by a city of Kelowna. The decision to establish domestic water metering within a Water Conservation Program was not driven by the occurrence of an extreme climate event or by any other urgent need but because it had been expected to be a good strategy to reduce tensions and costs associated with population growth (SHEPHERD et al. 2006). Important to mention that there was no water supply stress and adaptation was not associated with the fear of not meeting a growing water demand but with a good water management sense. In this case, there were no implementation constraints, which allowed deliberate implementation of metering concerning potential problems (SHEPHERD et al. 2006). Thereby, the study shows an example of the successful proactive adaptation that increased Kelowna's capacity to deal with potential unexpected climate impacts. This example supports the assumption that this type of opportunities occurs rather in developed regions where progressive attitudes towards sustainable development patterns prevail.

The results show that adaptation opportunities as factors aiming to prevent and/or overcome adaptation barriers are the most frequently observed ones. This evidence confirms the most regularly understanding of opportunities in the adaptation research as enabling factors or strategies. Opportunities in the function of drivers are viewed as catalysts of adaptation action and are also worth examining. Therefore, these two perspectives on the concept of adaptation opportunities will be considered more detailed in the next subsections.

4.3 Drivers of adaptation forcing adaptive measures

The findings demonstrate a various nature of drivers that trigger adaptation, including extreme events, leadership, political or higher authority encouragement, compliance with national and/or international commitments, and others (e.g. residential development, diseases outbreak, etc.). The following drivers are the most frequently observed and will be considered in a more extended way: climate-related extreme events and leadership (Figure 3).

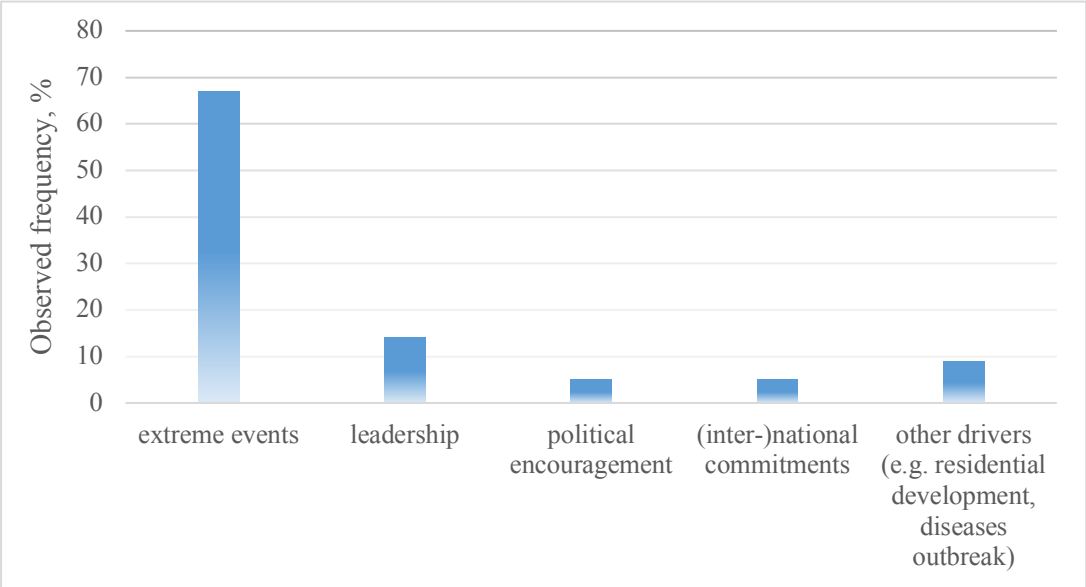

Figure 3. Drivers of climate change adaptation.

4.3.1 Extreme events as a driver of adaptation

It is reasonable that a strong climatic shock changes the perception of climate impacts and encourages adaptive actions. The importance of extreme events in triggering an adaptation action is extensively highlighted in the current adaptation literature. This is not surprising since the present results also demonstrate a reactive nature of present adaptation. The empirical evidence proves that there is correlation between adaptive measures being taken and external shocks, such as extreme events, which open a "window of opportunity" for adaptation (AMUNDSEN et al. 2010). This "window of opportunity" may vary from the implementation of adaptive measures, which have been already developed before but still did not get off the ground, to the changes in institutional settings (NAESS et al. 2005).

ADGER et al. (2007) claim that the policy environment might be more facilitative to changes in favour of climate adaptation directly after the occurrence of climatic disturbance. Individual climatic extreme events may refresh awareness of risks and lead to the achievement of consensus. This can result in a broader and new generated knowledge that can trigger action from a political perspective (ADGER et al. 2007). CHRISTOPLOS (2006) extends the list of the possible reasons of this phenomenon by arguing that individual extreme events may reveal the weaknesses associated with governed policies, institutions and inappropriate infrastructure as well as actors, which activities additionally encouraged risks. Similarly, OPPENHEIMER and TODOROV (2006) while discussing the psychological aspects of

global warming point out that a successful policy response can be provoked by previous failures.

However, a severe climatic disturbance does not necessarily lead to an immediate adaptation. Reconsideration and future development of policies and maintaining the initiative towards an appropriate adaptation are quite demanding processes. It is often observed that over time the willingness to act is gradually calling off (CHRISTOPLOS 2006). For instance, KIRCHHOFF et al. (2013) find a correlation between the occurrence of extreme events and an increased demand on climate information. The case studies from Georgia State, US, and Santa Catarina State, Brazil, confirm that stressed periods significantly increase the exchange and use of climate information. They serve as drivers for the climate information use since managers' awareness was still high due to experienced climate impacts on the resource system. To sustain the process of information production, its use and dissemination requires certain efforts that were lacking. This leads to a loss of such opportunity, as the sense of emergency is already gone (KIRCHHOFF et al. 2013).

In spite of the above, there is no need in rushing to the conclusion of a failure. One should rather anticipate a time-demanding process. Although adaptive responses are rather reactive, the empirical evidence still demonstrates undertaken efforts following the extreme events. Some following adaptive actions may result in running research projects or in establishment of commissions that look for the ways and strategies to prevent similar disasters (NAESS et al. 2005). In addition, the case of the Georgia State in the study of KIRCHHOFF et al. (2013) was analysed during the transition period of water management regime from a conventional one to the integrated water resource management, what makes it a bit uncertain in terms of potential institutional changes that were to come and the new role of information providing agencies.

Climate adaptation triggered by the occurrence of climate extreme events can be rather viewed as reactive and mainly short-term, with a low potential to comprehensively correspond to contextual factors and to the system's dynamics. Such ad hoc adaptation responses usually result in a temporary enhancement of the capacity to deal with adverse climate impacts because the intention to make a move towards more comprehensive adaptation decisions is often gradually calling off over time.

4.3.2 Leadership as a driver of adaptation

Another event that might force adaptation to occur is the appearance of a leader. In the context of climate change adaptation, leadership differs from its common understanding. It refers to the characteristics necessary to deal with complex problems: the way a leader assesses the problem, e.g. gathering and using information; how the decisions are generally taken, e.g. through open consultations in large groups or small ones; how crises are managed or how the dialogue with other stakeholders flows (VIGNOLA et al. 2017).

In relation to governance support, a leading role of some strongly engaged and experienced actors that promote adaptation is of particular interest. In the literature, leadership is quite often mentioned as one of the key drivers to adaptation through appearance of "a strongly committed, active, knowledgeable person" at the management or administrative level (RENDÓN and GEBHARDT 2016, p.20).

Leadership can be determinant at any stage of the adaptation process. As a driver to adaptation action, it is particularly important for initiating the adaptation process. EISENACK et al. (2014) acknowledge an important role leadership can play for adaptation action, particularly in its pre- and initial stages. Inspired leadership allows to establish "novel governance mechanisms and create a significantly changed context for decision making" (EISENACK et al. 2014, p.869). Similarly, HEINRICHS et al. (2009) aligns a crucial role to leadership in terms of pushing innovation in decision making.

The issue of leadership is slightly covered in the analysed case studies due to the lack of insights on the conditions, effects and consequences associated with the appearance of committed and leading individuals necessary for a more in-depth analysis. Several studies still argue for the importance of leadership for triggering adaptation. Thus, PULWARTY and MAIA (2015) addressing adaptation in complex rivers mention leadership as a driver to changes in climate impacts management. The effect of engaged individuals is more clearly observed by SHEPHERD et al. (2006) in their study on water climate adaptation in the Okanagan region, Canada. Certain individuals played a key role in the move towards implementation of a water conservation program: "X drove a lot of it – it would not have got done without him - if he hadn't taken a leading role" (SHEPHERD et al. 2006, p.50). A strong individual initiative also seems to be an important driver in local stakeholder planning groups

by pushing discussions on climate related issues and their subsequent inclusion into a planning process. The latter argument is not conclusive since a strong leadership can both support and hinder the use of climate information in decision making (WHITELY BINDER 2006).

Leadership is not necessarily restricted to its formal manifestation. Important is the quality of leaders' motivation and the guidance they provide to sustain adaptation over time and to overcome existing barriers, acting then as enabling factors to climate change adaptation (MOSER and EKSTROM 2010).

The appearance of a strong leader that pushes adaptation may contribute to the enhancement of a coping ability, for example, in terms of influencing the access to the resources required for implementation of adaptive measures. There is no certainty that once leaders trigger adaptation, their initiated actions will be in character with a long-term and comprehensive adaptation. For that to happen, a shift from a traditional leadership paradigm based on the leader and his followers towards the leadership oriented at creating conditions for innovation, supporting coordination, developing of new ideas is essential (MEIJERINK and STILLER 2013).

4.4 Opportunities as factors preventing and/or overcoming barriers to adaptation

Figure 4 presents an overview of identified recurrent opportunities to climate change adaptation in the function of preventing and/or overcoming barriers. The observed opportunities refer in large part to institutional settings (both formal and informal) that facilitate interaction, building networks and collaboration, leading to the increasing governance capacity to adapt. The findings emphasize the important role of providing and using climate information, which drives collaboration and is central for mainstreaming climate related issues into planning and management frameworks.

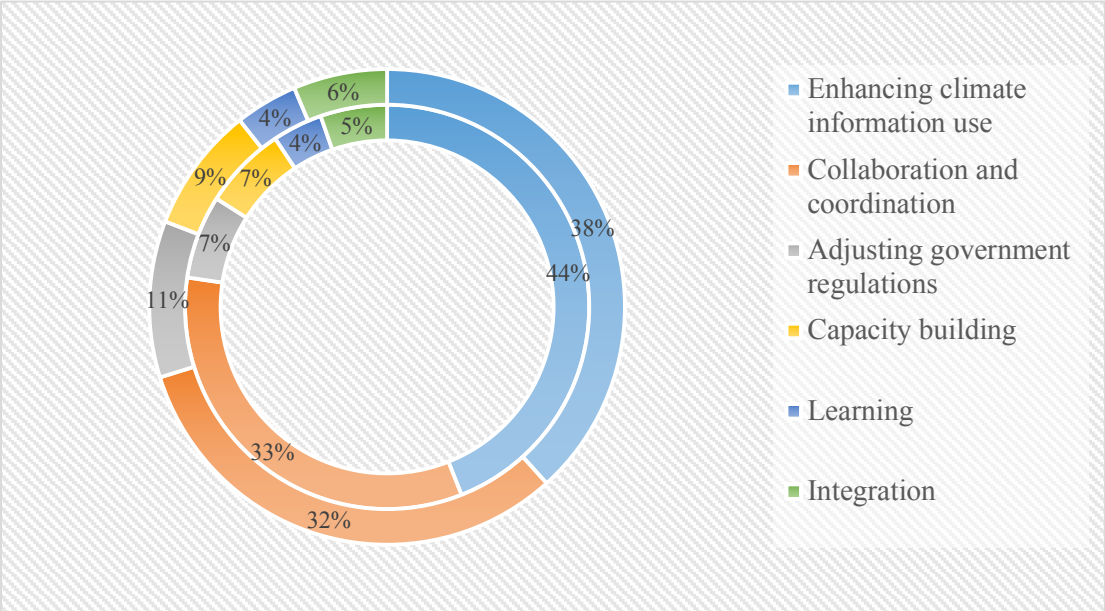

Figure 4. Opportunities as factors preventing and/or overcoming barriers to adaptation: the inner circle of the diagram depicts the percentage of the models that report on opportunities; the outer circle of the diagram represents the proportion of the articles, wherein the respective models were observed.

4.4.1 Enhancing climate information use

The use of climate change information for adaptation decision making is an important and the most observed enabling strategy to address adaptation barriers that constrain governance capacity in preparing adaptive responses to adverse climate impacts. This opportunity primarily helps to deal with a limited awareness and understanding of a climatic stimulus by enabling the use of necessary climate information (Table 3). Inclusion of climate information into planning and management practices contributes to the enhancement of adaptive capacity mainly by enabling evaluation of climate impacts that in turn forms a basis for development of adaptive responses to address these impacts.

Opportunities	No. of Models	No. of Studies	Codes	Barriers
Enhancing climate information use				
Recognition of climate change impacts	4	3	D11-A14-A03-O11	- Insufficient reason due to limited awareness of climate change - Managers' risk

				aversion or scepticism
Consideration of climate aspects	8	4	D12-A14-A31-AO3-O11	- Constrained capacity due to limited understanding of climatic stimulus - Constrained capacity due to limited information
Inclusion of climate information	17	7	D13-A14-AO2-O11 D13–A41-A44-AO2/AO3-O11-O12 D13-A42-A45-O11 D13-GS21-AO2-O12-O3	- Heterogeneous interests of actors about resource services - Heterogeneous interests about priority of adaptation - Path dependency: rules based on historical data - High transaction costs due to secure property rights with fixed allocations - Slow procedure of institutional change and associated with this high transaction costs
Research on climate change impacts	4	4	D14-A42-A44-O11	- Constrained capacity due to limited understanding of SES and climate stimulus

Table 3. Enhancing climate information use as an adaptation opportunity to prevent and/or overcome adaptation barriers.

A selected sample of multiple case studies allows observing various extents of climate information integration into a decision-making process (Figure 5). Primarily, recognition of climate change impacts associated with actors' awareness of climate stimuli is an important enabler for adaptation. It is mainly an individual perception of climate change impacts that influences the managers' willingness to consider adaptation along with other management needs. Adaptation requires modifications in or creation of new policies and practices in order to adjust to

different types of climate change (short- and long-term). Since these adjustments are time demanding, an earlier recognition and awareness of potential climate impacts are shown to be important in terms of giving time to develop the capacity to adapt (WHITELY BINDER 2006, FARLEY et al. 2011). Recognition of climate change impacts is a sort of informal acknowledgement of present or potential exposure to climate variability and/or change that is crucial for enabling a proactive planned adaptation.

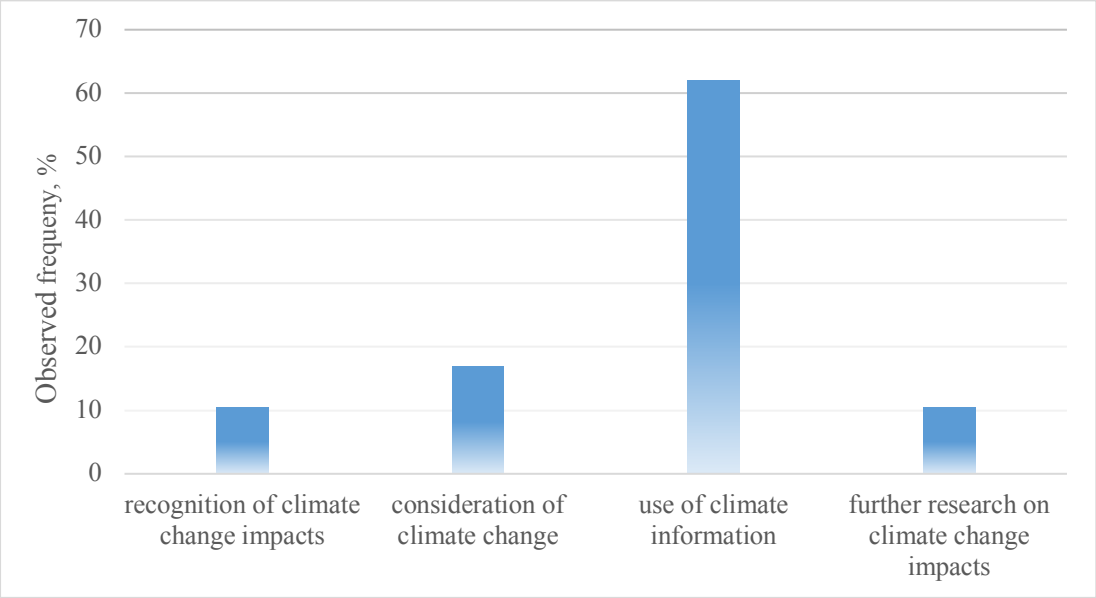

Figure 5. Inclusion of climate change information into planning and/or management frameworks.

Consideration of climate change aspects in planning and management practices involves discussions about climate change and investigations on its impacts. It means that there is already an interest in or awareness of climate impacts and risks, though climate information is not yet explicitly included into a planning and/or a management framework. The findings show that recognition and further consideration of climate impacts in decision making is more likely to occur in the systems under decentralized governance, e.g. by local planning groups. This can be explained by the fact that climate impacts are more realized at the local level (WHITELY BINDER 2006, HAMLET 2011). Therefore, such attributes as homogeneous beliefs and interest in climate change, familiarity and previous experience of actors with climate impacts as well as trust among stakeholders affect whether new aspects such as climate change will be discussed (WHITELY BINDER 2006). Additionally,

availability of financial resources motivates investigation of potential climate impacts.

Various types of climate information are already used on a routine basis in management practices within certain sectors. This information mainly refers to short-term weather forecasts that significantly limits its use to the daily management purposes (ZIERVOGEL et al. 2010). The use of climate information to assist adaptation involves consideration of seasonal forecasts, which incorporate an intra-annual variability, and therefore is a prerequisite for responding to longer-term changes (ZIERVOGEL et al. 2010). The use of projections on climate change, evaluation of data on extremes and mean values and interpretation of instrumental climate data likewise enable preparing longer-term adaptive responses (KIRCHHOFF 2013). Although climate information is to a certain degree already used in management, there is however a slow uptake of climate relevant information for decision making. A poor accuracy and availability of required information, uncertainty about climate forecasting, a low level of competence necessary for climate information interpretation, a poor understanding of climate stimuli effects and other barriers challenge the climate information use (ZIERVOGEL et al. 2010).

The findings demonstrate certain features that enable of climate information use for decision making. A successful coordination and integration of climate impacts is observed at the local level. This can be explained by the fact that a growing awareness of climate impacts and the actors' perception of the resource system's vulnerability to climate change motivate a further use of climate relevant information in decision making. The coordination of information and knowledge required for the integration of climate change aspects into practices is argued to be less impeded at the local scale due to a few decision-making entities and because governance process is largely built on the actors' interrelation within the same community (HAMLET 2011).

Formation of management councils subsequent from the transition from a centralized to a decentralized resource governance likewise enables integration of climate aspects into planning and/or management frameworks. Management councils and interface organizations play a bridging role at the sub-regional level. By interacting with water managers, these organizations help to increase the awareness of actors about potential climate affects (for example, by downscaling

global warming and demonstrating climate impacts at the local level) and encourage the use of climate information (KIRCHHOFF et al. 2013).

In the context of transboundary governance, cross-border organizations and other joint institutions are likewise characterized by collaboration and bridging efforts. This enables integration of climate information into planning through collaborative research, stakeholder integration and developing mutual priorities (WILDER et al. 2010, SINGH-PETERSON et al. 2012, COTS et al. 2009). Alternatively, establishing of Information Systems across boundaries represents an effective opportunity for the information exchange and its integration into development and planning practices (WILDER et al. 2010). Such Information Systems exercise coordination of data across various scales of decision making and between the parties involved and broker a necessary information for planning and decision making: "Co-production of scientific knowledge can influence policy within the region and encourage more sustainable planning. In the end, new communities of practice might emerge that institutionalize regional climate science and "climatic thinking" into their current and future water management practices, share institutional data within the community, and are committed to collaboration" (WILDER et al. 2014, p.926).

Nature conservation plans also provide a basis for a potential response to climate impacts by giving room for production and inclusion of climate information in reference to biological species. Such documents require updates and recurrent evaluations of new information (FARLEY et al. 2011). In comparison with current unwieldy regulatory arrangements, recovery plans are rather guiding documents and can be easier changed. This leads to a higher adaptive capacity in terms of increasing institutional flexibility. This strategy might be an efficient opportunity against a slow procedure of institutional change and associated to this high transaction costs (FARLEY et al. 2011, BOER 2010). Such plans guarantee per se their formal capacity, which implicates a longer-term perspective of adaptation. In a similar vein, flexibility of state planning or management acts in their potential to incorporate climate change aspects into the planning schemes results in a prioritized protection of vulnerable ecosystems (BOER 2010). This consequently attests a higher value of adaptation needs.

The use of climate information serves as a formal recognition of climate impacts and results in the equal consideration of climate issues along with other concerns on a long-term basis (WHITELY BINDER 2006). This allows not only addressing barriers associated with general lack of climate information availability and accessibility but also those concerning heterogeneous interests of actors about resource services and priority of adaptation. Additionally, the use of climate information implies regular updates and reliance on climate forecasts that are critical for preparing responses to a longer-term change. This revives traditional management practices based on historical records that assume the probability of climate shocks to occur based on their frequency of occurrence in the past.

Finally, the research on climate change impacts is enabling for alleviation of barriers related to a limited understanding of SES and climate stimulus (FARLEY et al. 2011, GILLON et al. 2015). A continuing evaluation of climate impacts coupled with the need for more detailed climate projections and their analysis is a necessary condition for building a supplementary adaptive capacity required for a longer-term consideration of climate aspects in the governance agenda.

The results show that a fruitful adaptation decision making largely relies on the scientific climate information (e.g. seasonal forecasts and climate change scenarios). Incorporation of climate information into planning and management practices serves as a longer-term enabling strategy to deal with future risks. This instead requires a dynamic communication between actors (e.g. by a more active stakeholder inclusion into decision making) and an improved coordination of climate knowledge and data (based on clear responsibilities across decision-making entities). Therefore, a rapidly increasing demand in climate information is one of the main reasons for the appearance of various types of collaboration networks. This argument brings it to the second most observed opportunity for climate change adaptation and will be discussed next.

4.4.2 Collaboration and coordination

Coordination problems are observed to be one of the most acute due to a complex nature of adaptation governance. It incorporates different sectors, scales and domains. There are mutual interdependencies among different actors with various interests and views that need to be coordinated (BIESBROEK 2014). It follows that adaptation governance entails interactions and a boundary crossing, a well-

functioning of which increases the overall governance capacity to address climate induced challenges (WILSON and TERMEER 2011).

At the same time, climate information use that is essential to adaptation decision making requires a high degree of cooperation as well. As previously discussed, management councils and cross-border organizations play an important role in awareness raising and climate information uptake through their bridging efforts. Therefore, collaboration is particularly crucial for enabling climate information production and use.

In this vein, the results clearly demonstrate pronounced tendencies towards a mutual formal but more importantly an informal cooperation aiming at either benefiting from common efforts through consolidation of technological, human and other resources or at collaborating on the knowledge and climate information production (Table 4).

Opportunities	No. of Models	No. of Studies	Codes	Barriers
Collaboration and coordination				
Coordination with beneficial effects	16	11	D51-GS321-O11 D51-GS322-O13 D51-A31-AO32-O13	- High transaction costs due to limited trust - High transaction costs due to scattered responsibilities - High transaction costs due to scattered responsibilities and heterogeneous interests about water services - Incompatible institutional incentives - Constrained capacity due to missing means - Short-time horizon of decision-making

Research networks and knowledge partnerships	9	4	D52-A44-A46-GS51-AO3-O11/12 D52-GS32-GS61-O11/12	- Insufficient reason due to limited awareness of climate change - Insufficient reason due to perception of climate change as a future problem - Constrained capacity due to limited information - Constrained capacity due to limited trust - Constrained capacity due to limited understanding of SES - Enforcement deficit - Restricted information uptake - Short-term focus of adaptive responses - Risk aversion or scepticism - High transaction costs of coordination - Limited horizontal coordination with heterogeneous interests - Heterogeneous interests about priority of adaptation - Path dependency: rules based on historical data

Table 4. Collaboration and coordination as an adaptation opportunity to prevent and/or overcome adaptation barriers.

Strengthening coordination across different levels of decision making as well as among governing entities at the same level is viewed as an opportunity for

establishing linkages for knowledge and resource flows in a multilevel governance. In this regard, a better coordination does not only benefit from reduced transaction costs of communication but also provides an opportunity for institutional reflexivity and learning, increasing thus the adaptive capacity of a governing system to deal with adverse climate impacts (HURLBERT and DIAZ 2013). Coordination efforts are critical for the establishment of clear roles and the distribution of responsibilities when governing adaptation activities. This positively enables adaptation by addressing the challenges related to the scattered responsibilities and heterogeneous interests about resource services and those associated with incompatible institutional incentives.

Common collaborative efforts within research networks and knowledge partnerships are crucial for supporting interactions between actors and informing adaptation decision making. Collaboration between scientists and stakeholders on the knowledge co-production merit a particular consideration as it is observed to be an innovative and effective mode of interactions that may deal with a wide range of barriers that are not merely related to the climate information use (see Table 4). Coordination of data and knowledge translates into a higher adaptive capacity of actors to prepare an adequate response in the face of climate variability. A feasible evaluation of climate impacts and available flexibility through the uncertainty integration and interventions in activities ensure the enhancement of adaptive capacity (WHITELY BINDER 2006, KIRCHHOFF et al. 2013).

The following types of collaboration were identified:

- Stakeholders' networks at the local level have potential to demonstrate a coherent flexibility in dealing with adverse climate impacts. There are few decision-making centres at this level of governance, which makes it easier for managers to communicate and build trust among them. This is instead a strong argument against complex fragmented governance systems. Additionally, stakeholders' efforts proved to be efficient in the context of collaboration on technical solutions to other challenges. This cooperation can serve as a good basis for promoting a joint management on climate impacts in a longer-term perspective, allowing thus coordination of climate information and related knowledge (HILL and ALLAN 2014).

- Governing agencies cooperate in order to increase their responsive capacity, namely by incorporating climate information in their management activities. This

makes them be able to control a decision-making process since ignoring climate change makes them vulnerable to the potential policy responses, which in turn may influence their responsibilities or management activities (HAMLET 2011).

- Scientists-stakeholders' partnerships particularly enhance production and usability of climate information and knowledge. A direct collaboration of stakeholders and climate scientists aims at improving stakeholders' understanding of climatic stimuli and its impacts on the governed resource system. It also reconciles information supply with concrete demand needs by integrating expertise from both sides, which increases capacity to comprehensively address the adaptation related problems (KIRCHHOFF et al. 2013). This kind of partnership implies long-term iterative interactions that allows for a continual social learning process, and therefore is likely to result in successful and sustainable societal outcomes (WILDER et al. 2010, KIRCHHOFF et al. 2013). The findings also show that the information seeking behaviour of actors associated with their awareness of climate impacts and the willingness to improve the quality of management generally motivates interactions with other actors for a common knowledge generation as well as cooperation with agencies that produce a specific climate information (KIRCHHOFF et al. 2013).

- Since climate impacts do not fit in with administrative boundaries, a transboundary management is very often challenged by its fragmented nature. The influence of different governance characteristics and various socio-economic settings of respective countries or regions additionally complicates the adaptation process. In this context, more flexible approaches to adapt are required. Joint institutional frameworks, e.g. in the form of cross-border organisations or collaborative projects, appear to be the most relevant for enabling integration of climate change adaptation into transboundary governance along with other management needs (COTS et al. 2009). These joint institutional arrangements seem to be able to reconcile multiple interests, balance priorities and to shape a favourable environment for the feasible intervention in various domains of activities (PULWARTY and MAIA 2015). For this to happen, a higher degree of coordination between multiple interdependent actors is required. Therefore, the bridging role of such transboundary organisations is critical for the enhancement of the governance adaptive capacity in cross-border regions (COTS et al. 2009). Such institutional

arrangements may serve as effective responsibility- and cost-sharing mechanisms and ensure the formal continuity of joint initiatives since the parties are often bound with long-term agreements (SINGH-PETERSON et al. 2012).

- Adaptation to a changing climate coupled with adaptation to existing institutional constraints lead to the formation of networks and partnerships with other user groups (WELSH et al. 2013). In this perspective, the combination of informal agreements with the actors' understanding of their interdependencies within a single SES translates into the flexibility in their operational activities. This manifests in an emerging opportunity for the resource users with almost no water rights to adapt to changing climate conditions (WELSH et al. 2013).

4.4.3 Adjusting government regulations

Formal institutional and governing mechanisms that prescribe interrelations within SES are important for enabling climate change adaptation, particularly by providing the required flexibility of institutional arrangements to deal with climatic variability and change. However, a current empirical evidence mainly demonstrates the converse. The present findings reveal certain opportunities for the flexibility enhancement, which involve interventions into governing institutional regulations to enable the preparation of proactive long-term adaptive responses (Table 5).

Opportunities	No. of Models	No. of Studies	Codes	Barriers
Adjusting government regulations				
Strengthening government regulations	1	1	D21-GS412-GS62-O3	- Poor implementation and enforcement of legislation mechanisms
Creating new government regulations and arrangements	1	1	D22-GS41-O12	- Heterogeneous interests about resource services - High costs of adaptation
Changing government regulations/institutional design	3	3	D23-GS21-GS41-O12	- Institutional path dependency: slow procedures of institutional change

				- Stalled social and institutional learning

Table 5. Adjusting government regulations as an adaptation opportunity to prevent and/or overcome adaptation barriers.

Strengthening government regulations and incentives with a particular aim to protect natural components of the governed SES could be one such opportunity. This strategy is feasible when the existing legislation mechanisms are often poorly implemented or enforced by government agencies (BOER 2010). In this context, it implies the enactment of stronger regulations and their further evaluation to determine whether such interventions appear to be successful (BOER 2010).

In case of an inconsistent integration of climate adaptation into policies and planning frameworks, interventions that are more decisive can enable adaptation (BOER 2010). New or changed institutional arrangements should be introduced to address the underlying causes of natural system's degradation associated with unsustainable development paths in other related sectors (BOER 2010). This mainly refers to policies that consider and prioritize the adaptive needs of ecosystems over other development needs.

These enabling strategies are quite context-specific in terms of their focus on conservation of the already degraded resource systems, which most likely will be more severely affected by climate effects. This can be a reason for their moderate observation within the examined sample of case studies. Instead, the results mainly report on opportunities associated with changes in institutional arrangements. Examples include the existing trading systems of resource rights and formation of inclusive treaties governing a common natural resource. These opportunities contribute to the enhancement of adaptive capacity by providing some extent of institutional flexibility.

A transfer of rights is an alternative way to reallocate natural resources without introducing changes in existing laws (HAMLET 2011). Completion of treaties may incorporate adaptive mechanisms that anticipate unexpected changes and support parties in adjusting to those changes on a longer-term perspective. Besides the strategies for a general resource distribution, such treaties consider changes in a resource provision in periods of climate shocks. It can be also agreed on a

compulsory amendment and a review of agreements, which is a good opportunity to update the treaty in view of potential changing contexts (KISTIN and ASHTON 2008). Conditions associated with a withdrawal from the treaty are also contemplated. Finally, joint commissions can be foreseen to design and integrate projects and processes specified by the treaty as well as to advice and monitor actions of the respective parties (KISTIN and ASHTON 2008). Such joint institutions have potential to recognize the need for adaptation and advise parties to initiate the adaptive action (KISTIN and ASHTON 2008). Therefore, the presence of flexible mechanisms allows for the determination of needs and problems and for balancing competing interests and implementing solutions in the context of uncertainty associated with climate change (HURLBERT et al. 2009).

4.4.4 Capacity building

Besides the function of creating a flexible institutional environment, government is also a powerful actor that provides required resources to support climate change adaptation, increasing thus a basic capacity of actors to adapt (Table 6). Capacity building is a quite straightforward enabling strategy to overcome barriers associated with the lack of financial, technological, human and information resources.

Opportunities	No. of Models	No. of Studies	Codes	Barriers
Capacity building	5	4	D6-A31/32/43-O13	- Financial constraints - Constrained capacity due to poor coordination of data - Limited capacity due to technological constraints - Constrained capacity due to limited understanding of SES

Table 6. Capacity building as an adaptation opportunity to prevent and/or overcome adaptation barriers.

The results demonstrate that government as well as external applied institutions support actors with the implementation of technical solutions, innovation of their adaptive practices, a supplementary research on climate impacts, provision of

accounting tools or reliable local climate projections, and by assuring the transparency of climate or vulnerability assessments (WEI et al. 2011, WHITELY BINDER 2006). This contributes not only to the enhancement of a basic adaptive capacity but also enables flexibility of actors to manage resources in the periods of climate shocks in conjunction with other enabling factors.

4.4.5 Integration

Assuming a complex nature of climate adaptation, integration of various aspects (e.g. social, economic, climate, political, etc.) and/or various actors involved into a decision-making process is a crucial strategy to deal with climate impacts. Considering adaptation in the context of complete systems aims at preparing joint beneficial adaptive responses and at producing more effective outcomes (ERNST and PRESTON 2017).

Opportunities	No. of Models	No. of Studies	Codes	Barriers
Integration	4	3	D3-GS31/32-GS51-AO3-O12	- Insufficient reason due to heterogeneous interests about water services - Top-down decision-making - Limited stakeholder participation - High transaction costs due to limited horizontal coordination and due to heterogeneous interests about resource services - Limited control of operator due to limited control in polycentric system

Table 7. Integration as an adaptation opportunity to prevent and/or overcome adaptation barriers.

Opportunities for integration in the context of adaptation governance manifest in various ways. On the one hand, it refers to the integration of economic goals, environmental incentives and management practices with sustainable approaches. Such integration translates into a joint and equal incorporation of heterogeneous

interests into a planning framework, including climate adaptation needs (ENGLE and LEMOS 2010). The understanding of interdependencies for decision making and a consequent joint consideration of these interconnected aspects allows addressing climate impacts in a dynamic and flexible way, increasing the capacity of a system to adapt.

Since generally institutional structures appear to react unwieldy, the establishment of joint institutional bodies or the creation of a smaller operational group involving the representatives of various actors permits to deal with climate shocks in a rapid and efficient manner (ENGLE and LEMOS 2010). This kind of integration implies a high degree of cooperation among actors to enable adaptation in a more flexible form.

Another way of integration occurs through a polycentric governance structure, which implies coordination among multiple actors and organizations across different levels and within the same level of decision making. This approach requires a higher degree of connectivity and coordination. This will enable a broad networking of actors rather than concentrating decision making at one particular level (COSENS and WILLIAMS 2012, HURLBERT et al. 2009). A polycentric approach incorporates horizontal and vertical levels of decision making, which reduces the transaction costs associated with a limited coordination and heterogeneous interests about resource services (PAHL-WOSTL and KNIEPER 2014, OSTROM et al. 1961). Therefore, a polycentric way of integration contributes to an increasing flexibility in addressing climate-induced challenges by enabling elaboration of common goals and strategies and by incorporating various interests into a decision-making process.

4.4.6 Learning

Learning is a broad category that includes various interaction processes between actors and/or institutions. This kind of interactions intend to address a complexity and interconnections across spacial and temporal scales, to raise awareness and support understanding of natural and human elements of joint SES, to contribute to a coproduction of knowledge or to the sharing of lessons and practices (LEBEL et al. 2010). The importance of learning has been widely recognised in the context of environmental governance and resource management as a strengthening mechanism towards sustainability and collaborative efforts.

The process of learning in its manifold forms is likewise observed to appear as an essential enabling component of adaptation. Generation of knowledge is important for informing adaptation decision making but knowledge alone is not sufficient to face climate-imposed challenges. A continuous process of collecting practices, sharing knowledge, building networks and supporting reflection represent enabling mechanisms for effective longer-term and sustainable adaptation paths. A social and institutional reflexivity appears to be a particular important attribute associated with learning processes (HURLBERT and DIAZ 2013). It strengthens adaptive capacity of a system by providing flexibility for the dynamic and effective responses to unpredictable changes. Reflexivity implies having ability to reflect and to learn from experience and interactions on a continuous basis, creating capacities to anticipate and to adjust to changing contexts (HURLBERT and DIAZ 2013). For instance, an effective social learning occurs through the discussed before direct interactions between scientists and stakeholders within research networks and knowledge partnerships (WILDER et al. 2010, KIRCHHOFF et al. 2013). It similarly may occur through other formal and informal ways of communication and information exchange that allows for a symmetrical learning as well as for learning from the effects of the implemented measures. Institutional learning and reflexivity highly depends on vertical and horizontal coordination. In the presence of these factors, it enables more flexible responses that are able to cope with a dynamic nature of climate variability and are open to experimentation. In this regard, institutional learning helps to avert institutional rigidity.

Learning contributes to the enhancement of adaptive capacity in that it helps to reduce informational and normative uncertainties (LEBEL et al. 2010). The latter implies uncertainty in terms of objectives and activities associated with the actors' perception of vulnerability and risk (LEBEL et al. 2010). Learning is important to empower stakeholders to affect the adaptation process, for example, through knowledge sharing. Informal networking appears to be flexible in quickly reacting to uncertain challenges (KIRCHHOFF et al. 2013). Establishing informal collaboration reduces the chance of conflict situations and promotes trust building among actors (LEBEL et al. 2010). Finally, by addressing heterogeneous interests of actors, learning attributes elements of fairness.

The empirical evidence shows that learning is largely embedded in and enables adaptation together with other opportunities, such as, for example, coordination and collaborative efforts. This is a good example of how opportunities act in an interconnected way. For this reason, learning closely associated with other opportunities was not explicitly coded as a separate opportunity in order to avoid confusion in categorisation.

Instead, another learning opportunities have been examined and were intrinsically attributed to this category. Those are connected to social learning as well, but separately from the processes of collaboration in their direct manifestations (Table 8). One this opportunity may refer to the so called "positive vulnerability" that enhances adaptive capacity in virtue of its continuous exposure to natural dynamics (WELSH et al. 2013). This constant exposure to climatic perturbations stimulates pertinent adaptive responses (WELSH et al. 2013). Learning based on past experiences with vulnerabilities to climate shocks allows continually and successfully addressing climate variability independently from unwieldy institutional arrangements, such as fixed property rights.

Opportunities	No. of Models	No. of Studies	Codes	Barriers
Learning	3	2	D4-GS6-O12	- Constrained capacity due to limited understanding of climatic stimulus and poor coordination of data - Stalled social learning due to rules based on historical data and limited understanding of SES - Organized resistance to oppose adaptation measures - High transaction costs due to secure property rights with fixed allocations

Table 8. Learning as an adaptation opportunity to prevent and/or overcome adaptation barriers.

Finally, learning occurs to be an enabling strategy when dealing with organized resistance that opposes adaptation measures. For instance, a public education process through meeting, consultation and discussion sessions contributes to the awareness raising and understanding of climate stimulus and its potential adverse effects (SHEPHERD et al. 2006). Likewise, illustration of beneficial effects adaptation measures can obtain helps to alleviate public scepticism, mistrust and concerns about high adaptation costs (SHEPHERD et al. 2006).

4.5 Chapter summary

The presented results report on the main observed opportunities to climate change adaptation revealed through the systematic review of case studies. The findings demonstrate a prevalent reactive nature of climate adaptation at a global scale since reactive responses to extreme climate events are widely reported. In this regard, it is not surprising that adaptation is mainly driven by single events, such as the occurrence extreme climate events or the appearance of a leader. Playing the roles of catalysts, drivers to adaptation force adaptive measures. However, such adaptation is characterized as a short-term and spontaneous. The findings show that the triggered intention towards more comprehensive adaptation decisions is often gradually calling off over time.

The study likewise identifies opportunities in the function of factors preventing and/or overcoming adaptation barriers that by contrast enable longer-term proactive adaptation paths. Despite a heterogeneous nature of manifestations of this kind of opportunities, the findings have shown recurrent constellations of factors explaining their appearance. This translated in their systematic classification, which differentiates between six adaptation-enabling factors:

- enhancing climate information use;
- collaboration and coordination;
- adjusting government regulations;
- capacity building;
- integration;
- learning.

The results particularly emphasize the important role of provision and use of climate information in enabling decision-making processes. Coordination and

cooperation among actors and institutional structures is essential for the effective climate information production and use as well as for establishing linkages for knowledge and resource flows. The role of informal interactions and knowledge cooperation is especially promising both for the inclusion of climate adaptation into planning and/or management practices and for trust building among actors, essential for their multifarious management cooperation in view of climate change.

Government support in provision of flexible institutional frameworks and various kinds of resources required for a successful adaptation is certainly important. However, learning and integration processes are equally essential to ensure flexibility in addressing climate-induced challenges by enabling elaboration of common goals and strategies and by incorporating heterogeneous interests into a decision-making process.

5 Discussion

5.1 Introduction

This part of the thesis summarizes and analyzes the key findings of the study. It provides fruitful insights on adaptation opportunities based on the results of the systematic review of the selected case studies. Further, limitations of the study are addresses. Finally, the chapter presents and discusses possible counterfactuals in the functioning of adaptation opportunities and their possible implications for adaptation policy making and future research.

5.2 Exploring opportunities to climate change adaptation: key results

The systematic review of the selected case studies on adaptation in the river basins worldwide shows the following results:

1) Adaptation opportunities appear in close connection to barriers.

While barriers to adaptation can be seen as factors that impede the adaptation process, opportunities, by contrast, enable it. In this regard, barriers and opportunities outbalance each other and can be seen as impeding or facilitating characteristics of the variables an adaptation action depends on (BIESBROEK 2014). In this connection, opportunities in large part inherit characteristics attributed to barriers:

- Opportunities and barriers are supplements in terms of their influence on adaptive capacity. Hence, while barriers lead to a diminishing adaptive capacity, enabling factors aim at achieving the enhancement of adaptive capacity (BIESBROEK 2014). The results show that depending on the objectives of adaptation and its context, the enhancement of adaptive capacity mainly involves evaluation of climate impacts, a presence of flexibility mechanisms to manage uncertain nature of those climate impacts and the general enhancement of a basic capacity of the governing system in terms of a necessary resource provision.

- Similar to barriers, it is assumed that the nature of opportunities would depend on the objectives of adaptation and on its context (BIESBROEK 2014). Enabling as well as impeding factors are context-specific since both emerge as the result of interacting elements (actors, government and resource systems, and climatic exposure) and conditions in a particular context.

- Alike barriers adaptation opportunities vary from cognitive or motivational to institutional (BIESBROEK 2014). Consideration of adaptation as a societal process implies focusing its analysis on individual actors or group of actors. The reason for this is that actors and their interrelations shape institutional environment, in which the adaptation process intends to occur, and which in turn determines the initial adaptive capacity of the affected system. In this vein, the results demonstrate that adaptive capacity varies contextually across different actors (SMIT and WANDEL 2006, BIESBROEK 2014). First, this happens because opportunities largely depend on perceptions and beliefs of actors. For instance, the awareness of the need to intervene depends on personal interests and views regarding existing barriers in the adaptation process. Overall, the perception of being exposed to climate variability is crucial for supporting adaptation. The results often show the transition from cognitive opportunities into institutional, outlining a primary role of individual awareness of actors. Secondly, the results point at a crucial role of actors' interactions that significantly enable climate knowledge use and activate common efforts that lead to the increasing capacity to deal with climate change and variability.

- Most adaptation opportunities as well as barriers do not directly address climate change adaptation apart from a few of them (mainly opportunities concerning climate information use and associated uncertainty regarding climate projections) (BIESBROEK 2014). Many enabling factors ultimately do not specifically address climate change adaptation, but interfere with a wider range of environmental and governance issues in general. For instance, the necessity and importance of institutional coordination, particularly in the context of complex government structures is not an innovative strategy. It has been widely discussed in the scientific literature dedicated to the resource governance in general (PAHL-WOSTL and ROSS 2009, EDELENBOS and TEISMAN 2013, BRESSERS and KUKS 2013, VAN DER VALK and KEENAN 2011, COOLEY et al. 2013).

2) The obtained results demonstrate a cumulative effect of adaptation opportunities that act in their entirety and not isolated.

If to take a closer look at the identified opportunities, it is discernible that they are very interrelated. Thus, learning and integration both largely depend on coordination and collaborative efforts. Establishing linkages in turn enables climate

information uptake and resource flows. This gives a room for exploring more aggregated solutions that will seamlessly integrate various enabling elements to meet an adaptation demand.

This significantly increases the capacity to avert complex mechanisms that impede adaptive responses. In this context, adaptation opportunities do not merely alleviate or overcome existing barriers in the adaptation process but also aim to set a comprehensive and sustainable adaptation path. In this way, opportunities contribute to planned and longer-term adaptive responses that would deviate from a reactive nature of adaptation. Rather than simply consider opportunities as "mirroring" representations of barriers, one should focus on looking for innovative solutions that in part are already embedded in the known opportunities or are at the interface of their interaction.

Among observed enabling factors and strategies boundary interactions, i.e. collaboration between scientists and stakeholders, feature one of such innovative opportunities. This kind of collaboration not only aims at establishing linkages between actors but also at increasing climate information use in decision making, reconciling thus information supply with the concrete demand needs (WILDER et al. 2010, KIRCHHOFF et al. 2013). By integrating expertise from both sides, it increases the capacity to comprehensively address adaptation-related problems (KIRCHHOFF et al. 2015). Moreover, an iterative long-term character of these interactions contributes to the social learning process, which is more likely to result in successful and sustainable societal outcomes (KIRCHHOFF et al. 2015, BRILEY et al. 2015). The empirical evidence demonstrates that concerned managers show more interest in research and are ready to invest in climate information production (KIRCHHOFF et al. 2013). They are more open to cooperation with scientific and non-scientific agencies, which may make for the establishment of long-term relationships and enables trust building, and therefore, encourages a longer-term planning (KIRCHHOFF et al. 2013, WILDER et al. 2010, PULWARTY and MELIS 2011, PULWARTY and MAIA 2015). This logic outlines that such innovative strategy is closely associated with other revealed opportunities, e.g. enhancing climate information use, integration, social learning, which allows to deal with a complex nature of adaptation barriers, addressing them simultaneously.

These findings correlate with those being published in the recent studies on climate change adaptation that prioritize boundary interactions and co-production of knowledge because of its effective outcomes and multifacetedness in dealing with adaptation barriers (ZIERVOGEL et al. 2016, BRILEY et al. 2015, KIRCHHOFF et al. 2015). Some recent studies on barriers and opportunities in the adaptation governance point out at the importance of focusing on interdependencies as well, pointing out at the integrating sectoral interrelatedness (ERNST and PRESTON 2017).

3) Adaptation opportunities otherwise appear as drivers for adaptation, forcing adaptive measures.

The findings demonstrate a reactive nature of adaptation mostly triggered by the occurrence of extreme climate events. This questions the ability of current management and decision-making processes to assure a long-term resilience of affected systems (BIRKMANN et al. 2008, AMUNDSEN et al. 2010). Drivers to adaptation provide a space for a potential change that could occur in various domains of decision making (AMUNDSEN et al. 2010). This change usually appears to be unplanned and often automatic. In most observed cases, such reactive responses refer to formal institutional changes initiated by government, e.g. creation of specific councils, institutional innovations, changes in management plans and programs, etc. However, the outcomes of these responses are often ambiguous in terms of their effectiveness due to their spontaneous nature and unclear objectives (BIRKMANN et al. 2008). Alternatively, the appeared opportunity for adaption actions is often gone together with the sense of the emergency (KIRCHHOFF et al. 2013, ADGER et al. 2007). Rarely, the responses were planned and structured, pursuing long-term objectives.

These findings correlate with those often presented at the current stage of the adaptation research (for example, BIRKMANN et al. 2008). They point out that a strategic reflective learning that will promote a comprehensive and longer-term adaptation does not stem from past extreme events.

5.3 Limitations of the study

The present study on adaptation opportunities faces certain limitations. First, selection of primary case studies is based on the research of EISENACK and OBERLACK (2017) that discusses adaptation barriers of water governance in river

basins. In this regard, selection of primary studies was guided by other conceptual foundations, with a focus on barriers to climate change adaptation. Therefore, the selected case studies provide an extensive analysis of adaptation barriers in the context of collective decision making, while enabling strategies and factors are not at the primary focus. This implies that the identified opportunities largely rely on the reported successful strategies that proved to be efficient in terms of adaptation outcomes.

It is important to mention that the analysed studies mostly focus on vulnerability assessments and analyse intentional climate change adaptation options, anticipating potential barriers and speculating on the effects opportunities will have in future. In this vein, assumptions regarding enabling effects the revealed opportunities exert and their influence on the enhancement of adaptive capacity need to be drawn with caution. Moreover, a selected sample of primary studies with initial focus on barriers implies the extended presence of opportunities as factors to prevent and/or overcome. This limits exploring other types of opportunities that are not directly related to barriers.

Secondly, the study reviewed literature from scientific journals written in English. Inclusion of grey literature and scientific literature in other languages could have expanded the number of case studies, and likewise reported manifestations of various types of adaptation opportunities.

Further, an exploratory nature of the present research, i.e. relying on a small-size sample of case studies, has implications in terms of the findings generalization. In the same view, an exploratory research does not allow for making definitive conclusions. A systematic review of various case studies implies different interpretations of adaptation, meaning that researchers usually imply their own frameworks that affect understanding of adaptation processes. This in turn has implications for making general assumptions concerning adaptation opportunities.

The coding procedure used to identify models for the analysis involves some limitations as well. By setting the unit of analysis at the level of the model, i.e. a causal statement involving adaptation opportunities, the information uptake is limited. Moreover, some models refer to the research question of a paper, which implies that they have been studied and particularly addressed. Other models tend to

appear in the discussion and/or conclusions. This means that they have been mainly speculated upon. In this case, the emergence of the "mirroring" opportunities to adaptation barriers is very likely.

Eventually, the examined studies are limited by their own research questions and provide insights relevant for their interpretation. This specificity influences the inclusion of information in a study and leaves some facts aside that might be relevant for examination of adaptation opportunities. The listed limitations do not seem to weaken the obtained results. They help to synthesize important aspects that should be taken into account when relying on the findings.

5.4 Implications for policy

The results show that adaptation opportunities are closely linked to barriers. In this regard, recognition of existing barriers in the adaptation process leastwise allows for a potential identification of adaptation opportunities (in a speculative, "mirroring" way). The findings likewise demonstrate that otherwise adaptation opportunities act as drivers for adaptation, mostly associated with the occurrence of an extreme climatic event or with the appearance of a leader. This implies that if adaptation is driven by leaders and/or extreme events, a planned anticipatory climate change adaptation does not seem to be compatible with present decision-making processes. In the following, the important insights in favour of these statements as well as other important implications for policy making are presented.

5.4.1. A diminishing role of formal institutions

The role of formal governing institutions is seen as crucial for facilitating climate change adaptation in two broad ways: by preparing a planned adaptation and by increasing the basic capacity of a system to adapt. However, governing institutions can equally impede climate adaptation by its persistence and path dependency, which creates barriers to adaptation. In the context of water governance, some opportunities to deal with this kind of barriers were identified. These opportunities mainly refer to the changes in institutional settings. For instance, modifications in an institutional design at least during shortfall periods can be a good opportunity to increase flexibility in times of climate disturbances (water stresses, etc.). This is best illustrated in the case of the Yakima River basin: an attempt to diverge from water laws dated by the 19th century and based on a prior

appropriation rule was made by creating water markets or banks that allowed some flexibility in water transfer between users (HAMLET 2011).

However, this opportunity appears a problematic when brought in in another context. This implies that the desired effect of an emerging flexibility by transferring water rights may not obtain fruitful results. For example, in Chili a relatively high level of stakeholders' autonomy and flexibility in managing solutions turns into the opposite from desired effect and increases the water systems' vulnerability to climate change (HILL 2013). This can happen because the principles, on which water rights and legislation are based, may not embrace conservation and protection of scarce and vulnerable water resources and associated ecosystems (HILL 2013).

It was also explicitly demonstrated that awareness and recognition of climate impacts by actors often appear to be more effective than available institutions in developing capacity to prepare responses to climate impacts (KIRCHHOFF et al. 2013). It, first, encourages climate information intake, and secondly, prompts collaboration and interactions between various actors. Thus, multiple agencies' and user groups' networks prompt horizontal coordination, which results in production and use of information on climate impacts and in reduced transaction costs associated with the information and resource exchange. Moreover, collaboration with other actors results in long-term sustainable interactions between them that encourages social learning processes and leads to building trust.

Herewith, formal institutions appear to have a minor influence on motivating climate information use. The findings show that ultimately the individual water managers' behaviour driven by the awareness of climate impacts stimulates consideration and inclusion of climate aspects in planning frameworks. This might support the idea of a primary focus on the maintenance of social processes since institutional adaptation is characterized by a slow uptake (ZIERVOGEL et al. 2016).

5.4.2 Climate change information use

The findings show that the inclusion of climate information into management and planning practices is necessary to plan sustainable operational responses, especially intended for a longer-term adaptation. This implies a more formal recognition of climate change aspects in management settings. This opportunity is

the most observed one within the selected sample of case studies. In this regard, it is widely demonstrated that many management and planning frameworks have potential to incorporate climate information. For water management, this implies integration of seasonal forecasts and climate change projections into a hydrological modelling as well as evaluation of data on extremes and mean values and interpretation of instrumental climate data.

There are several ways to integrate climate information into a decision-making process, e.g. through the formation of management councils or cross-border organizations in the case of transboundary governance, through coordination and integration of climate impacts within local watershed units, and through various conservation and planning or management acts. Formation of management councils, cross-border organizations and local watershed units seem to be promising due to the effective collaboration and coordination of information and knowledge required for integration of climate change aspects into practices.

Incorporation of climate information into conservation and planning or management acts is however problematic. In case of the former, adaptation policies address maintenance of (vulnerable) natural systems in a long-time perspective and aim to avoid its larger degradation under climate change. This implies that governments prioritize conservation and management of water ecosystems over other needs (land use, urban development, etc.). If adaptation options are designed to maintain vulnerable natural systems, the problem usually appears in the resistance to implementation of alike policies since it competes with other social needs (BOER 2010). Additionally, as soon as being listed, endangered species are under control of federal jurisdictions, which implies multilevel governance activities. On the one hand, this can enable adaptation through additional sources of information. On the other hand, it can hinder adaptation due to a multiplicity of governing layers (FARLEY et al. 2011).

In case of state management or planning acts, the problem is related to the existing legislature that is poorly implemented or not supported by government in a proper manner. “Many wetland and river systems continue to be degraded by urban development, agricultural and industry activities, with the result that condition of wetlands and river systems across the region continues to decline (EPA 2008). If existing government policies have proven inadequate to address the broader impacts

from development on freshwater and estuarine resources, then they may also lack the capacity to alleviate more extreme climate change impacts" (BOER 2010, p.11).

Besides the trade-off between adaptation of water resources and other development needs, there are some other aspects to consider. The findings point out at the importance of collaboration efforts in inclusion of climate aspects into decision making. This factor is considered as high-potential in terms of trust building. Nevertheless, despite high levels of interaction and trust between actors, climate information can still not be well integrated into decision making because of some other managers' own pursued goals or interests. This includes an attempt to control resources, competition with similar organizational bodies for funding, or lack of integration and capacities (WHITELY BINDER 2006, KIRCHHOFF et al. 2013). For instance, the study of WHITELY BINDER (2006) on the local watershed planning in the Washington State shows that climate information uptake could be used as a good reason for lobbying for the additional reservoir construction or for setting apart instream water needs in periods of water scarcity.

While using climate information it is crucial to consider climate change as a nonstatic. Climate records imply spatial and temporal changes; this is why it is extremely important to update climate information as baseline conditions tend to change (GILLON et al. 2015). In the context of water management, this can lead to the overestimations regarding water supply and demand in a long-term perspective (PULWARTY and MAIA 2015). Moreover, the issue of uncertainty in climate projections remains. When planning adaptation measures, one can underestimate projected climate effects on a resource. This may translate into the constrained flexibility of built infrastructure to react to more severe climate impacts (BOER 2010). The use of improved modelled predictions that include forecasts to control changes and their effects on outcomes represents an opportunity for delivering an accurate information for water adaptation governance. Additionally, a scenario planning and transdisciplinary analysis may help to address the challenges associated with a nonstatic nature of climate (GILLON et al. 2015).

To summarize, enhancing climate information usage in management frameworks might seem to be a relatively easy approach since it requires slight changes and is easy to implement. This option goes over well among governments aiming to implement adaptation. As arguments above show, it cannot always play a role of a

facilitating factor since not all policies and operational practices are able to respond on equal terms and, besides, can lead to the same challenges that non-climate proved policies and management activities have (BOER 2010). In this perspective, equally important is to include climate information into planning by incorporating climate projections into a hydrological modelling and by using detailed local scenarios on climate impacts (WHITELY BINDER 2006, ENGLE and LEMOS 2010, FARLEY et al. 2011, GILLON et al. 2015, HAMLET 2011, KIRCHHOFF et al. 2013, PULWARTY and MELIS 2011).

5.4.3 A move towards sub-regional and local adaptation: a straightforward solution?

Many identified opportunities appear to function more effectively at the lower level of decision making, local or sub-regional, e.g. climate information use, collaboration and learning (WHITELY BINDER 2006, FARLEY et al. 2011, HAMLET 2011, HURLBERT et al. 2009, HURLBERT and DIAZ 2013, KIRCHHOFF et al. 2013). Operation at the local level of governance allows making fast and effective decisions in contrast to the unwieldiness of a centralized governance (HAMLET 2011). It reduces transaction costs of communication among managers and favours building trust and cooperation, on which depends whether the climate change issues will be discussed at all (WHITELY BINDER 2006). Local watershed planning is characterized by integration of all actors that are directly affected by their decision making. It favours addressing competing needs during the stressed periods and reduces transaction costs associated with the heterogeneity of interests about water services and adaptation (ENGLE and LEMOS 2010). The literature on adaptation likewise favours local governance as being best able to cope with the expected climate impacts (AGRAWAL 2008, NORDGREN et al. 2010, BROOKS 2002).

However, in application to water governance in river basins, many aspects of a local-scale planning and adaptation depend on the whole basin. An additional governance complexity can be challenged by a transboundary context and a rich history of upstream-downstream interdependencies. Thus, there is a need to coordinate multiple decision-making centres to address issues at a basin scale. A polycentric approach allows this coordination and leads to an increasing flexibility and a better horizontal coordination in the created networks (COSENS and WILLIAMS 2012, HILL 2013, OSTROM et al. 1961). This is best shown in the case of

Switzerland, a highly decentralized country, where local water management is mostly under the communes' functional control, receiving a necessary support from cantons (HILL 2013). The latter gives a full autonomy to the lower level of governance in planning and decision making. However, this sovereignty equally hinders coordination of joint efforts in the whole basin (HILL 2013).

Local governance is effective while managing reactive responses on climate perturbations. Nonetheless, the evidence shows that herewith it can hinder a longer-term management. In Switzerland, water management in Canton Valais is characterized by tensions between different levels of governance since water rights on the Rhone belong to the canton while the tributaries of the Rhone are under the local communes' control (HILL 2013). This tension leads to the impediment of a comprehensive longer-term adaptation. Likewise, the autonomy of Chilean water managers, flexible to trade water rights mainly results in short-term solutions. It simultaneously undermines their chances towards a joint and more sustainable decision making in the light of more severe challenges induced by climate change on a long perspective (HILL and ALLAN 2014).

Another argument for the need of coordination across the governing levels is a limited capacity of local water agencies to cope alone with climate impacts. Governance at the local level is crucial due to its integrating role of local interests and knowledge. However, government capacities are limited, and from this perspective, state governance is seen as a powerful actor that can provide with required and lacking resources to support climate change adaptation (HILL 2013). The call for coordination between governance levels corresponds to the ideas of balancing top-down and bottom-up decision-making approaches in the adaptation literature (HURLBERT and DIAZ 2013, HILL 2013, HUNTJENS et al. 2010).

In reference to water governance, integrated water resource management (IWRM) aims to establish a multi-sectoral governing approach, integrating various levels of governance as well as various socioeconomic and environmental aspects of water resource management. This approach to water governance points to balance top-down and bottom-up strategies through a better coordination and stakeholders' integration into the decision-making process. In the water management research, IWRM was considered effective due to its main characteristics listed above (RADIF 1999, DAVIS 2007, PAHL-WOSTL et al. 2007). However, a growing concern has

emerged regarding meeting the IWRM objectives in terms of its practical implementation. This issue has been also observed in the analysed case studies and will be introduced below.

The results depict that integrated water management enables climate information use through the establishment of boundary institutional bodies at the basin level that promote provision of climate information. Iterative interactions between such organizations and water managers have a high potential to result in the effective use of climate information, which increases the overall capacity to respond to climate impacts (KIRCHHOFF et al. 2013, ENGLE and LEMOS 2010, PULWARTY and MAIA 2015, HURLBERT and MONTANA 2015, HURLBERT and DIAZ 2013). However, in reality the IWRM regime does not always guarantee the success.

When compared with conventional management (dominated by a top-down governance approach) in terms of climate information use, the latter shows a better effect than IWRM due to the individual awareness and interest of water managers in climate change (KIRCHHOFF et al. 2013). A higher level of awareness leads to a more active cooperation with organizations that provide climate information and results in climate information integration in a planning process. Therefore, "…rather than whether a boundary organization is in place or not, it is the character of these knowledge production and transfer systems and their interaction with decision-makers that seems to exert the biggest influence on rates of information use" (KIRCHHOFF et al. 2013, p.15). This confirms the previously discussed argument about a diminishing role of formal institutions to deal alone with climate-induced impacts.

The implementation problems of IWRM are particularly apparent in developing countries due to the rigidity of water governance regimes that opposes the required flexibility for integrated management (KIRCHHOFF et al. 2013, HURLBERT and MONTANA 2015). In spite of being decentralized, federal governance still significantly influences decision making on the lower levels to the extent of policy-making control and formation of basin councils (ENGLE and LEMOS 2010).

The practice also shows that in some cases, collaboration among members and trust building are not enough to translate into an effective information use. In the context of water governance, this is clearly demonstrated in some States of Brazil.

Boundary councils are lacking the resources to assure water management practices with reliable information sources. This results in an increasing mistrust among managers in the provided climate information and forces them to stick to a conservative approach of water management without any regard for efficiency (KIRCHHOFF et al. 2013).

5.5 Recommendations for future research

Current research on opportunities to climate change adaptation is emerging. At present, most studies on climate adaptation conclude with some short suggestions how to support the adaptation process. Those largely refer to observed adaptation barriers and are context-specific. This is why there are no particular unified models of the processes that facilitate adaptation apart from broad categories, which are too common. Therefore, a further work on understanding of such context-specific determinants is promising (MOSER and EKSTROM 2010).

In this vein, future research on climate change adaptation might focus on exploring and studying innovative solutions to deal with complex mechanisms that impede adaptation. This includes research on multifaceted strategies to enable adaptation that have potential to integrate context specificity and to assure a long-term and sustainable function of affected systems.

A reactive nature of adaptation responses currently prevails in adaptation decision making. A crucial work remains in effectively applying the knowledge gained from existing case studies to support adaptation more broadly (BIRKMANN et al. 2008). Past experience and lessons learned are of a particular importance to facilitate the strategic reflective learning to promote a comprehensive adaptation.

A further examination of different types of opportunities is likewise encouraged. For example, an empirical evidence on effective adaptation responses that engender ancillary benefits for a system of concern might be an important aspect in favour of adaptation. A more detailed examination of how and what benefits can adaptation processes generate will be a contribution towards this end.

The importance of individual cognitive perceptions of climate change impacts and its implication for climate adaptation is likewise worth to emphasize. Particularly, in conjunction with the review of roles formal and informal institutions play in governing adaptation. A growing influence of informal interactions on

supporting adaptation opens room for reconsideration the leading role of formal institutions.

The question of an appropriate level of effective decision making remains a cornerstone for both climate change adaptation and water governance. Ongoing debates on centralized versus decentralized governance approaches need to shift from their focus on one particular level of decision making and search for the ways to balance and integrate top-down and bottom-up strategies. In respect to water management, more insights on current decentralization and participatory approaches in water governance would be fruitful for better understanding of their potential to incorporate climate change adaptation. Additionally, exploring determinants of water governance capacity appears to be promising both for addressing a multitudinous nature of water governance and for governing adaptation of water resources.

5.6 Chapter summary

The key findings of the systematic review of case studies on water governance adaptation report on a close correlation of adaptation opportunities with the identified barriers in adaptation processes. Adaptation opportunities and barriers appear to be supplements in terms of their influence on adaptive capacity. This implies that barriers to adaptation act as factors that impede the adaptation process, while opportunities by contrast enable it. Examining adaptation opportunities from this perspective shows that they in large part inherit characteristics attributed to barriers. In this regard, revealing existing barriers in the adaptation process allows for a potential identification of adaptation opportunities (in a speculative "mirroring" way).

While some adaptation opportunities represent straightforward solutions, other may act cumulatively when enabling adaptation. This means that adaptation opportunities are often very interrelated. This allows for finding integrative and innovative solutions that significantly increases the capacity to avert complex mechanisms impeding adaptive responses. One such example is boundary interactions between scientists and stakeholders that translate into multiple positive and enabling effects on adaptation. Future research on exploring and studying innovative solutions to deal with complex mechanisms that impede adaptation will be definitely fruitful.

These findings have certain implications for policy making. Since interactions between actors appear to play a critical role for supporting adaptation efforts, formal institutions seem to have minor influence on motivating climate adaptation. In addition to that, the actors' awareness and perception of climate impacts effectively enables climate information uptake and supports adaptation initiatives. By contrast, policies and operational practices do not seem to be able to respond to adaptation needs on equal terms and can lead to the same challenges that non-climate proved policies and management activities have.

If not in relation to adaptation barriers, opportunities otherwise appear as drivers to adaptation, mainly in the form of extreme events or leadership. This denotes a reactive nature of current adaptation practices. These events usually open room for an institutional change. However, this change is often unplanned and automatic. A strategic reflective learning that will promote a comprehensive and longer-term adaptation often does not stem from past extreme events. If adaptation is driven by leaders and/or extreme events, planned anticipatory climate change adaptation does not seem to be compatible with present decision-making processes. A crucial work remains in effectively applying the knowledge gained from existing case studies to support anticipatory adaptation.

6 Summary

Adaptation to climate change currently appears to be a necessary response to increasing adverse effects imposed by climate change and variability. Although a growing consensus on the need of comprehensive adaptive actions exists, the empirical evidence mostly demonstrates a challenging nature of adaptation. At present, the adaptation literature focuses mainly on existing tensions associated with implementation of adaptive responses. In this regard, exploring opportunities to climate adaptation is certainly fruitful, particularly taking into consideration that a well-established conceptualization of opportunities for adaptation is still missing. The present study aimed to address this gap by defining and characterizing opportunities to climate adaptation. In doing so, it also intended to reveal what opportunities occur in the governance of climate adaptation, in what way they are related to adaptation barriers and what they mean for adaptation decision making.

Due to a manifold character of climate change adaptation, the study has focused on water governance adaptation in river basins. A systematic review of the adaptation literature helped to develop a more concrete understanding of opportunities. Based on the general understanding of opportunities as favourable factors or circumstances that determine progress or advancement, four different perspectives on the concept of opportunities to climate change adaptation have been identified:

1. Opportunities as additional benefits from adaptation measures;
2. Opportunities as available (and yet unexploited) capacities to adapt;
3. Opportunities as drivers of adaptation forcing adaptive measures;
4. Opportunities as factors preventing and/or overcoming barriers to adaptation.

This categorization provides a new perspective on adaptation opportunities by revealing various manifestations of opportunities and by making a distinction between them in accordance with the timing of the adaptation process, their origin and intentions, and the effects on adaptive capacity.

For a more comprehensive examination of adaptation opportunities and their relation to adaptation decision making, the coding and subsequent analysis of selected case studies on water governance adaptation in river basins worldwide was performed.

The results point at a close correlation of adaptation opportunities with identified barriers in the adaptation process. This implies that opportunities outbalance barriers and can be seen as facilitating characteristics of the variables an adaptation action depends on. Adaptation opportunities tend to inherit characteristics attributed to barriers. In this connection, recognition of existing barriers in the adaptation process allows for potential identification of opportunities to enable adaptation.

Despite a heterogeneous nature of manifestations of this kind of opportunities, the findings have shown recurrent constellations of factors explaining their appearance. In this way, the findings particularly underline the important role of climate information use in enabling decision-making processes. Coordination among actors and institutional structures appears to be essential for the effective climate information production and use and for establishing linkages for knowledge and resource flows. The role of informal interactions and knowledge cooperation is especially promising for integrating climate adaptation into planning and management practices and for trust building among actors. Government support in provision of flexible institutional frameworks and required resources for a successful adaptation is important. However, learning and integration processes seem to be equally essential to ensure flexibility in addressing climate-induced challenges.

The observed interconnected relationships among these enabling factors translates into cumulative effects when supporting adaptation. This allows for revealing the integrative and innovative solutions that are significantly increasing the capacity to avert complex mechanisms that impede adaptive processes.

Otherwise, adaptation opportunities often appear as drivers to adaptation. They trigger adaptive measures, providing an action space for opportunities to occur. Resulting changes are however often unplanned and automatic in nature. This denotes the reactive nature of current adaptation practices. It demonstrates that a strategic reflective learning, which could promote such adaptation, does not stem from past experiences with climate variability. This implies that the important role of opportunities in supporting a long-term and comprehensive adaptation does not appear to be compatible with current prevailing decision-making processes. A crucial task remains in effectively applying the knowledge gained from existing case studies to support anticipatory adaptation more broadly.

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I hereby declare that the present thesis has not been submitted as a part of any other examination procedure and has been independently written. All passages, including those from the internet, which were used directly or in modified form, especially those sources using text, graphs, charts or pictures, are indicated as such. I realize that an infringement of these principles which would amount to either an attempt of deception or deceit will lead to the institution of proceedings against myself.

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