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Review papers

Adapting to climate change by water management organisations: Enablers and barriers

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ABSTRACT

Climate change will be particularly experienced though the medium of water. Water organisations, that are managing societal and ecological needs for water, are therefore likely to experience the impact the most. This study reviews the current literature regarding adaptation to climate change by water management organisations and associated barriers.

Literature on adaptive capacity is growing and a general consensus is emerging on the determinants of adaptive capacity, although variations exist regarding how it is to be evaluated, enhanced and applied to policy making due to its dynamic, contextual and latent nature. Since adaptive capacity is hard to measure and successful adaptation difficult to define, some studies focus on the existence of adaptation attributes of organisations. Studies reporting successful adaptation are minimal and barriers of adaptation are being discovered as adaptation research transitions into implementation. But the root causes of these barriers are often overlooked and the interconnectedness of the barriers is poorly addressed.

Increasingly, combining top-down and bottom-up approaches to adaptation is being recommended due to the limitations of each. However, knowledge regarding how organisations operating at different scales can enhance adaptive capacity of other organisations operating at another scale is lacking due to the few studies of inter-organisational networks across scales. Social networks among actors are recognised as a key factor to enable adaptation. However, network studies generally focus on individual actors and rarely between public agencies/organisations. Moreover, the current literature is inadequate to understand the relationship between adaptation enabling characteristics, barriers and adaptation manifestation. The review demonstrates that research on understanding the emergence and sustenance of barriers is urgently required. Addressing these knowledge gaps will help to improve the design of adaptation strategies, thereby improving the ability of water management to address the ongoing challenges of climate change.

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1. Introduction

Changes in recent climate and associated impacts on natural and human systems have been reported widely (IPCC, 2014a). These include changing precipitation and snow melt altering water resources (Arnell, 2004; Kundzewicz et al., 2008) and hydro(geo)-logical behaviour (Holman, 2006), leading to floods and droughts (Barnett et al., 2005; Jaswal et al., 2015; Rajeevan et al., 2008; Singh et al., 2016; Upgupta et al., 2015; Xu et al., 2009). Climate change is also likely to impact water quality (Whitehead et al., 2009) including increased sediment loads during floods (Wulf et al., 2012) and increased contaminant concentration during the dry season (Whitehead et al., 2009). Temperature increases are likely to increase water demand (Holman, 2006), particularly in irrigation (Wang et al., 2014), due to increased evapotranspiration. In short, the immediate and direct impacts of climate change are going to be particularly experienced through the medium of water.

The compelling and growing body of evidence of a changing climate points to the urgent need for adaptation actions to compliment mitigation (Füssel, 2007; Simonet and Fatorić, 2015) due to the emissions already committed (IPCC, 2007) and the inadequacy of international agreements for reducing greenhouse emissions (Spash, 2016). The Intergovernmental Panel on Climate Change (IPCC, 2014b, p. 1758) defined adaptation as 'the process of adjustment to actual or expected climate and its effects'. Within human systems, adaptation is aimed at moderating or alleviating harmful effects or to take advantage of the beneficial opportunities (Noble et al., 2014) through anticipatory, autonomous and/or planned actions (Mimura et al., 2014; Preston et al., 2013). However, actions solely focused on adapting water management to climate change are rare (Charlton and Arnell, 2011) or at least are often not named as such (Moser and Boykoff, 2013), since strategies and investment plans are driven by many other short term concerns (Klein et al., 2014), particularly in developing economies with competing developmental pressures. Therefore, adaptation is often integrated into developmental plans (for e.g., Sietz et al., 2011).

Significant deficiencies in climate preparedness do exist even in highly industrialised countries such as Australia, UK and USA (Preston et al., 2010) which are often presumed to have higher capacity to deal with climate variability. Yet, adaptation is especially relevant for developing countries which are struggling to address the challenges being posed by climate variability (Ford et al., 2014; Krysanova et al., 2010; Nyamwanza and Kujinga, 2016) compounded by other competing developmental priorities. The limited research on adaptation (Mertz et al., 2009; Spires et al., 2014) mostly focuses on vulnerable communities (Archer et al., 2014; Hammouri et al., 2015; Younus, 2010), sectors (Dany et al., 2015; Marothia, 2003; Upgupta et al., 2015) or physical systems such as river basins (Pandey et al., 2011; Sud et al., 2015) but rarely on the organisations that administer water; with a few exceptions including Arnell and Delaney (2006); Engle (2012); Tompkins et al. (2010).

This review paper aims to consolidate the state of the art in climate change adaptation for water management and identify the key knowledge gaps for successful implementation of adaptation strategies. Therefore, this review paper brings together current literature on adaptation with the aim of identifying characteristics that enable or hinder adapting water management to climate change by water management organisations (government agencies, private companies, municipal corporations, non-governmental organisations, river basin management organisations or any agency that administers or supplies water to the users and/or involved in water related disasters such as droughts and/or floods). It is divided into five sections. Section 1 has identified the need for consolidating the current knowledge on climate and argues the relevance of this review in the current discourse on climate change adaptation particularly for water management. After the brief introduction to the aim and significance of the review in Section 1, Section 2 brings together the current knowledge on adaptation by water management organisations by drawing knowledge from adaptation studies in general, the assessment of adaptive capacity and barriers and how adaptation is manifested in likely implementation of adaptation strategies. This section also draws out the current discourse on how adaptation is understood and supplemented and exposes the lacunae in the current discourse. This section exposes how adaptation is understood and the processes involved in adaptation implementation. Section 3 establishes the case for enabling adaptation and reducing barriers through inter-organisational networks. It, thus, brings together the current approaches towards enabling adaptation through a process identifying the known adaptation barriers and how they can be addressed. Finally, Section 4 draws the current gaps in knowledge before conclusions are drawn with key messages in Section 5. Section 4, thus, points out to the need for addressing these key barriers in order to enable the successful implementation of adaptation actions. This leads to the conclusion, in Section 5, which shows that adaptation involves the management of these barriers if adaptation is to be successful.

2. Adaptation by water management organisations

Organisations rarely remain static and virtually all undergo changes in their activities and processes. For water management organisations, these changes may be triggered by external factors such as water scarcity, natural calamities, legislation, political reforms, and technological change, and/or by internal factors such as change in leadership and management, policy and innovation (Saleth et al., 2000). Since climate change is projected to increase water demand and reduce availability (Jiménez Cisneros et al., 2014), adaptation options in the water sector are generally categorised into supply side and demand side management (Arnell et al., 2001). Adaptation in the water sector needs to go beyond structural measures (Stakhiv, 2011) and incorporate other measures including forecasting/warning systems, insurance

instruments and other ways to improve efficiency of water use and related behavioural change through economic and fiscal instruments, legislation, and organisational change (Crabbé and Robin, 2006). Therefore, water management organisations themselves, such as agencies and companies that are supplying water to the users, for example, need to adapt in order to avert and reduce undesirable impacts and take advantage of new opportunities.

Approaching from organisational change theories, Berkhout (2012) distinguishes organisational adaptation into three perspectives: a) utility-maximising, b) behavioural and c) institutional, such as legislation and formal and informal rules. Under the utility-maximising approach, organisations pursue adaptation if 'the cost of making the effort is less than the resulting benefits' (Mendelsohn, 2000; p. 585). As the costs and benefits of alternatives and the costs of inaction need to be known, utility-maximising approaches cannot take into account the uncertain nature of climate impacts and issues of perception, interpretation, and the learning processes of organisational adaptation (Berkhout et al., 2006), leading to mostly reactive adaptation (Berkhout, 2012). Berkhout (2012, p. 93), arguing from the traditions of behavioural economics and organisational studies, concurred that 'actors do not conform to the expected tenets of utility theory' and instead use 'rules of thumb' in responding to new situations and hence stressed the importance of perception and interpretation of potential risks. Moreover, organisations are shaped by the constraints of external factors such as laws, regulations and the socio-cultural-politico-economic context in which they are embedded (Pahl-Wostl, 2009; Roggero, 2015). As the recognition of the need for adaptation transitions into construction of adaptation strategies and plans (Mimura et al., 2014), questions regarding whether or not the organisations managing the system have the capacity to adapt to the new and uncertain situations become even more urgent.

2.1. Assessment of adaptive capacity

In the climate adaptation discourse, adaptive capacity, defined as 'the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences' (IPCC, 2014b; p. 1758) of climate change, is increasingly gaining research interest (Preston et al., 2015). In the context of water management organisations, it may be understood as the capacity of the organisation to maintain or improve levels of services despite climate and socio-economic change. Adaptive capacity is, therefore, largely shaped by the capacity of decision makers within the organisation to grasp the potential challenge and the seriousness of the risks, plan suitable strategies and implement them (Brown et al., 2013).

Examples of various approaches of assessing adaptive capacity in the literature, not specific to water management organisations, can be categorised depending on the method of assessment, scale, and sector:

a) Method of assessment: indicators (Gupta et al., 2010; Hinkel, 2011; Pandey et al., 2011), participatory (Henly-shepard et al., 2014; Munaretto et al., 2014; Smajgl, 2010), scenario based (Dessai et al., 2005; Flörke et al., 2011; Pilli-Sihvola et al., 2014)
b) Scale of assessment: individual households (Aulong et al., 2012), community (Murtinho, 2016; Pearce et al., 2012; Whitehead, 2009; Younus, 2010), local municipalities (Hogarth and Wójcik, 2016; Shi et al., 2015), regional (Juhola and Kruse, 2015), basin (Engle and Lemos, 2010), national (Clarvis and Allan, 2013; Haddad, 2005), multilevel (Pahl-Wostl, 2009; Westerhoff et al., 2011).
c) Sector of assessment: water (Engle, 2007; Pandey et al., 2011), forest (Brown et al., 2010), building construction (Hertin et al., 2003)

The generic determinants of adaptive capacity in the above studies are similar to those proposed by Smit et al., (2001), although the selection of the indicators depends on the purpose, scale, or sector of each study. It indicates that there is near consensus regarding the generic determinants of adaptive capacity, which Juhola and Kruse (2015) differentiated into three dimensions of awareness, ability and action (Table 1). In Table 1, the availability of adaptive capacity determinants is indicated by the availability of various components in the third column.

Despite the above consensus, contentions exist when it comes to methods of evaluation and its applicability to policy making (Engle, 2011; Hinkel, 2011). Challenges of adaptive capacity evaluation pertains to its latent nature (Bohensky et al., 2010; Engle, 2013), that it is contingent upon other economic and technological factors (Fitzsimons et al., 2009; Moench, 2010), and its temporal dynamics. Moreover, due to uncertainty in climate change projections and impacts, adaptive capacity evaluation and application in policy making remain challenging (Hinkel, 2011).

2.2. Attributes of adapting organisations

Since evaluation of adaptive capacity is challenging, identifying the availability of 'adaptation attributes' (Lonsdale et al., 2010; Wilby and Vaughan, 2011) and 'adaptation readiness' (Ford and King, 2015) has been adopted by some studies for evaluating adaptation by organisations. Wilby and Vaughan (2011) and Lonsdale et al., (2010) identified adaptation attributes based on the existing characteristics of the organisations, as organisations which are adapting to current climate variabilities are more likely to have greater adaptive capacity (Dessai and Hulme, 2004). Attributes of adapting organisations are inherent within those organisations and organisations that aim to adapt need to acquire these attributes. These attributes include a) visionary leaders who can articulate adaptation goals and acquire resources, b) clearly stated adaptation objectives which are regularly reviewed, c) prioritised actions based on comprehensive risk and vulnerability assessments, d) implementable guidance and training to the operating staffs, e) flexible organisational structures that enable learning and decision making within the existing code of practice, f) adaptation pathways being guided by low-regret adaptive measures,

Table 1
Dimensions, determinants and indicators of adaptive capacity in water organisations (based on Juhola and Kruse (2015)).

Dimensions	Determinants	Indicators
Awareness	Knowledge and awareness	Availability of knowledge
		Awareness of adaptation options
		Awareness of resources availability
Ability	Technology	Technology for monitoring and treatment
		Capacity to undertake research
	Infrastructure	Availability of dams, canals, wells
	Human capital	Leadership
		Technical expertise
Action	Institutional and governance	Effectiveness of governance
		Ability to monitor and evaluate
		Clear adaptation strategies
		Equity
	Economic resources	Availability and accessibility to fund
	Autonomy	Ability to decide and act independently

g) partnering with other organisations for resources pooling, h) monitoring and reporting progress against clearly defined targets, and i) effective communication internally and externally.

Ford and King (2015) use similar criteria to capture the actions being done to plan and prepare for adaptation, such as the existence of a) political leadership for adaptation, b) institutional organisation for adaptation, c) decision making and stakeholder engagement d) availability of usable science e) funding and f) public support for adaptation and applied to pilot studies to assess the 'adaptation readiness'. However, the approach has similar challenges to evaluating adaptive capacity, including data limitations and developing indices for evaluating 'readiness'. Knowledge regarding how readiness factors actually drive adaptation action on the ground remains limited due to the nascent state of studies on actual manifestation of adaptation (Moser and Boykoff, 2013). Just as the availability of adaptive capacity in itself does not ensure adaptation, adaptation readiness does not mean that adaptation will automatically occur (Tilleard and Ford, 2016). Therefore, although the concept of adaptation readiness goes beyond adaptive capacity (Tilleard and Ford, 2016) it is insufficient to understand how adaptation will unfold, particularly in the presence of adaptation barriers and limits.

2.3. Barriers to adaptation

As climate change adaptation studies progress from impact assessment to policy and planning (Mimura et al., 2014) to implementation, challenges for successful adaptation are being discovered (Eisenack et al., 2014). Although organisations seldom remain static, they also exhibit inertia in some aspects (Berkhout, 2012) due to barriers which are both external and internal. Achieving the desired adaptation goals is contingent not on adaptive capacity alone but also upon many factors (such as socio-economic and cultural) that shape decision makers' perceptions of risks (Liu et al., 2016; Smith et al., 2014) and their willingness to act (Adger et al., 2009; Gifford et al., 2011; Grothmann et al., 2013) or prioritise actions.

With the increased recognition for the need to understand the factors and circumstances that stop, delay or reduce adaptation effectiveness (Biesbroek et al., 2014), barriers to adaptation have been defined from various perspectives, with terms such as limits (Dow et al., 2013a), challenges (Fünfgeld, 2010), obstacles (Bedsworth and Hanak, 2010), and constraints (Klein et al., 2014) often being used synonymously. However, Klein et al. (2014, p. 907) differentiated adaptation constraints from limits by defining the former as 'factors that make it harder to plan and implement adaptation actions' and the latter, following Adger et al. (2009); Dow et al. (2013); Islam et al. (2014); Moser and Ekstrom (2010), as 'The point at which an actor's objectives or system's needs cannot be secured from intolerable risks through adaptive actions' (Klein et al., 2014, p. 907). A consensus is emerging among researchers to use 'limit' to refer to natural and physical challenges whereas 'barrier' more commonly refers to the challenges emerging from sociological and institutional factors (Barnett et al., 2015; Moser and Ekstrom, 2010), that 'can be overcome with concerted effort, creative management, change of thinking, prioritization, and related shifts in resources, land uses, institutions, etc.' (Moser and Ekstrom, 2010, p. 2).

Moser and Ekstrom (2010) structured their conceptualisation of barriers according to three phases of adaptation – understanding phase, planning phase and management phase. Barriers at the understanding phase include the unavailability or inaccessibility of information and knowledge, legitimacy, credibility, trust and receptivity to the information and willingness and ability to use it (Moser and Ekstrom, 2010). At the planning phase, leadership roles regarding authority and the ability to identify risks and opportunities, assess and devise alternative adaptation strategies and build consensus, credibility and trust are essential. Traits of the governance system regarding control over the processes of policy making and resources allocation play an important role in determining outcomes in the planning phase (Berrang-Ford et al., 2014), as actors' perception of control can limit deliberations (Moser and Ekstrom, 2010). Currently, empirical understanding of barriers in the management phase are limited (Moser and Boykoff, 2013) due to the recentness of the climate change adaptation (Moser and Ekstrom, 2010).

Empirical studies that specifically focus on adaptation barriers are relatively recent (Biesbroek et al., 2014). Most studies to date have focused at the local level, such as municipalities or local communities, and rarely at the national level or across scales, with Clarvis and Allan (2013) an exception. The barriers reported from case studies mostly related to cognitive barriers such as the inability to understand the risks contextually (Jones and Boyd, 2011; Shemdoe et al., 2015) and make sense of adaptation alternatives, or lack of information and data relevant to the scale of their influence (Amundsen et al., 2010; Baker et al., 2012; Pasquini et al., 2013). Assumptions of inability to change make some actors surrender to the situation (Jones and Boyd, 2011), while lack of local autonomy (Crabbé and Robin, 2006) and inaction by other organisations at a scale above the local bodies (Carlson and McCormick, 2015) were also reported as critically hindering adaptation. Lack of trust (Clarvis and Allan, 2013), interest (Pasquini et al., 2013), leadership (Measham et al., 2011), climate scepticism (Baker et al., 2012; Engle, 2012) and conflicts of interests (Pandey et al., 2011) were also reported as adaptation barriers. Inadequate financial resources, infrastructure, focus on short-term issues and competing developmental priorities (Engle, 2012) and legislation issues, such as unclear roles of actors (Amundsen et al., 2010) and lack of consistent and clear policy guidelines from state and federal governments (Baker et al., 2012), and cultural normative attitudes such as apathy and trust (Engle, 2012) can also hinder or slow down adaptation. This means it is difficult to ascertain or conclude that the mere availability of adaptive capacity will eventually lead to adaptation manifestation without addressing these adaptation barriers.

2.4. Adaptation manifestation

Adaptation manifestation can be understood as how successful adaptation will appear when barriers have been overcome and the desired goals of adaptation are met (Smit and Wandel, 2006). Eliciting opinions from a range of experts, Doria et al. (2009, p. 815) defined successful adaptation as 'any adjustment that reduces the risks associated with climate change, or vulnerability to climate change impacts, to a predetermined level, without compromising economic, social, and environmental sustainability' (Doria et al., 2009). However, few empirical studies exist from which insights can be drawn to conclude that adaptation in water organisations, such as those in the UK (Jude et al., 2017; Arnell and Delaney, 2006), was successful are few because adaptation planning rarely specify 'clear goals, endpoints, metrics or criteria for success' (Moser and Boykoff, 2013, p. 9; Jude et al., 2017). Moreover, the reports of adaptation being embedded within organisations are confined to industrialised countries (Berrang-Ford et al., 2011; Westerhoff et al., 2011; Jude et al., 2017), and mostly to the water supply, flood control and construction sectors (Tompkins et al., 2010). Adaptation being trickled down to the local organisations is scarcely evident and is mostly government-driven (Tompkins et al., 2010).

Manifestation of adaptation in developing countries, where water is administered by government organisations with different legal authorities, are poorly studied (Sud et al., 2015). In many of

the developing economies, such as India, water supplies, flood control, hydropower generation and inland navigation are controlled and operated by government organisations with limited local autonomy as compared to water companies in industrialised countries. Hence, it is difficult to apply learning experiences from developed economies to the developing countries, where competition for limited available resources continues to be a major challenge.

3. Enabling adaptation

Adaptation actions take place within a hierarchical structure of different organisational bodies operating at different levels that interact, influence, enable or hinder adaptation actions at another level (Adger et al., 2005; Lyle, 2015). Decision makers operating at different scales respond to the decisions made by actors at another scale (Smajgl and Prananingtyas, 2009), so that the capacity of organisations to adapt to the changing climate can be enhanced or undermined by the actions or inactions taken by actors beyond the organisation. Understanding the likelihood of an organisation adapting to the changing climate will involve understanding the influences from organisations operating at different scales or tiers of governance (Smajgl and Prananingtyas, 2009). This is particularly so in highly bureaucratic forms of governance where multiple organisations at multiple levels perform complimentary or overlapping functions (Azhoni et al., 2017a).

Recent studies on adaptation have shown that both public and non-governmental organisations – including research and academic organisations – play a crucial role in enabling adaptation (Adekola, 2012; Agrawal, 2010; Frantzeskaki et al., 2014; Wang et al., 2013; Azhoni et al., 2017b) at multiple scales (Kirchhoff et al., 2015; Pahl-Wostl, 2009). Water management organisations, therefore, need to inter-act with other agencies and sectors for adapting their management to climate change (Berkhout, 2012; Wilby and Vaughan, 2011; Azhoni et al., 2017b). Moreover, when internal resources are limited, organisations may need to acquire resources from beyond their operating scale to enhance their capacity (Vedeld et al., 2015; Azhoni et al., 2017b).

Managing water in changing climatic conditions, compounded by growing demands due to other developmental pressures, requires effective collaboration across scales and sectors to reduce competing policy agendas (Vedeld et al., 2015), enhance efficient sharing of limited resources and increase learning experiences. Recognising the need for multi-stakeholder and multi-sectoral engagement in water management and climate change adaptation, literature on inter-organisational networks, which was previously concentrated in the business and services sector, is emerging (Adekola, 2012; Inderberg, 2012; Steinberg, 2009; Azhoni et al., 2017a). However, the flows of knowledge and resources from higher levels of government through cross-scale networks that shape the temporal dynamics of climate adaptation (Lyle, 2015; Azhoni et al., 2017a) are inadequately studied to understand how socially equitable and sustainable adaptation to climate change can be enhanced (Azhoni et al., 2017b). Given that climate change impacts and adaptive capacity vary between sectors, actors and regions (Grothmann et al., 2013; Prutsch et al., 2014), local studies are required to draw out sociological perspectives on adaptation (Amaru and Chhetri, 2013) in order to complement national adaptation policies (Azhoni et al., 2017b).

3.1. Devolution of adaptive capacity to organisations operating at different levels

Organisations operating at different levels; from national to regional and local have both distinct and complementary roles in developing and implementing adaptation strategies (Adger et al., 2005; Fidelman et al., 2013; Nalau et al., 2015; Azhoni et al., 2017b). The extent of involvement of the various stakeholders in the design and application of adaptation measures shapes their outcome (Juhola and Westerhoff, 2011; Azhoni et al., 2017a). This is particularly so for water management, where adaptation can involve basin level management organisations, regional and national governments and local municipal bodies (Bisaro et al., 2010; Finger et al., 2006; Lebel and Garden, 2008; Mollinga et al., 2006; Pittock, 2011; Wilby and Wood, 2012). Moreover, this multi-level organisational interaction is shaped by the governance and organisational structure (Bizikova et al., 2015; Dannevig and Aall, 2015; Lyle, 2015; McGloughlin and Sweeney, 2011; Schreurs, 2010; Vedeld et al., 2015; Azhoni et al., 2017a). However, knowledge regarding how organisations operating at different levels operate and inter-act with one another, and how such interactions, or the lack of, create enabling mechanisms or hinder adaptation is limited (Amundsen et al., 2010; Dannevig and Aall, 2015; Vedeld et al., 2015; Azhoni et al., 2017a) due to a lack of frameworks to understand these complex structures. Therefore, more empirical studies are required to understand how the prevalence or absence of adapting attributes of organisations operating at one scale affects the adaptive capacity at another scale (Pahl-Wostl, 2009) in various socio-economic contexts (Azhoni et al., 2017b).

3.2. Inter-organisational networks for adaptation

In theory, networks are 'self-organising, collaborative, non-hierarchical, flexible, and topological' and 'the conditions of possibility and actions of network participants' are generally considered as 'a property emerging from the relationship with other participants rather than by their own inherent characteristic' (Leitner and Sheppard, 2002, p. 148–149). Nonetheless, networks are also not without hierarchy and a few members can dominate leading to political struggles and conflicts. Network theory analysis goes beyond socio-political studies that look at individual organisations (Steinberg, 2009) and includes the importance of non-technical approaches to planning procedures (Lienert et al., 2013). Since climate change is a multi-dimensional issue, the need for a multi-dimensional adaptation strategy by involving multiple stakeholders across scales can hardly be ignored.

Studies regarding the importance of networks between municipal bodies (Fünfgeld, 2015), experts (Rousselin, 2015), non-profit organisations (Steinberg, 2009) and individuals for climate change adaptation (Dow et al., 2013b; Aulong et al., 2012) and sustainable management of resources (Baird et al., 2015; Bodin and Crona, 2009) are emerging. The existence of networks enhances adaptive capacity (Brooks and Adger, 2005), enabling adaptation to take place through both formal organisations and networks across actors at various scales (Juhola and Westerhoff, 2011; Tompkins et al., 2010). Networks allow organisations to cross organisational boundaries and blur formal categories, providing 'a constellation of relationships that can be activated when needed, can be perturbed for new information or ways of doing, or simply turned to for an extensive store of knowledge' (Lejano and Ingram, 2008; p. 251). As the ability of a wider set of actors to plan adaptation is greatly enhanced by the presence of an effective network, understanding stakeholder networks enables the key opportunities and barriers to the flow of specific information to be determined (Ziervogel and Downing, 2004).

3.3. Transboundary organisations

In complex systems where multiple actors from various sectors are expected to be involved, transboundary organisations ('organisations that transcend multiple boundaries' - Sternlieb et al., 2013,

p. 118) are increasingly recognised as playing a key role in enhancing adaptive capacity (Kalafatis et al., 2015; Kirchhoff et al., 2015; van Enst et al., 2016). Such organisations include "boundary organisations" that mediate between science and policy and act as 'organisational structures that make collaboration possible by engaging actors on the basis of their convergent interests' (Sternlieb et al., 2013; p. 120). On the other hand, bridging organisations connect the actions between the various (types or groups of) organisations (McKenzie Hedger et al., 2006; Gawith et al., 2009; Tompkins et al., 2010) and act as 'conduits between social networks with the potential to link diverse nodes of expertise for collective action' (Sternlieb et al., 2013, p. 121) and provide 'an arena for knowledge co-production, trust-building, sense making, learning and horizontal collaboration and conflict resolution' (Berkes, 2009, p. 1695). Likewise, Brown et al. (2013) and Loorbach and Rotmans (2010) highlight the crucial role of bridging organisations and change agents in enabling sustainability transition. As the same organisation can mediate between science and policy as well as between organisations operating at different scales vertically, or between different types of organisations or groups of organisations, the terms are sometimes used interchangeably.

4. Discussion

The literature surveyed has identified the inter-relationships regarding knowledge concerning a) climate change impacts and adaptation needs (Section 1), b) factors that enable adaptation (Section 3), c) factors that hinders adaptation: barriers (Section 2.3) and d) adaptation manifestation (Section 2.4) which are synthesised in Fig. 1. Thus Fig. 1 brings together the various strands of climate change adaptation reviewed in the previous sections. For example, assessment of the potential impacts of climate change, manifesting through the reduced availability and reduced quality of water, and increase in demands and increased floods risks discussed in Section 1, provides the information and knowledge required for enabling adaptation planning (Section 2.2).

Besides the availability of information and knowledge, the literature surveyed thus far pointed out that other resources such as technology, infrastructure, finances and conducive institutional mechanisms, highlighted in Part B of Fig. 1 and elaborated in Sections 2.1 and 2.2, are necessary for enabling adaptation. However, in spite of the availability of adaptation enabling factors (elaborated in Sections 2.1 and 2.2, and highlighted in Part B of Fig. 1), certain factors such as a) cultural and normative behaviour, b) cognitive barriers, c) rigid and outdated laws, d) bureaucratic procedures, and e) uncertainty in climate change projections and limited resources can hinder adaptation. These are collectively termed barriers and highlighted in Part C of Fig. 1 and Section 2.3.

Evidently, it emerged from the literature surveyed that transboundary organisations (Section 3.3), which bridge the gaps between various sectors and actors and inter-organisational networks (Sections 3.2), play a crucial role in overcoming some of the barriers elaborated in Section 2.3. This is highlighted in Part C of Fig. 1 by suggesting that transboundary organisations and inter-organisational networks represent two pillars of adaptation.

All these factors are not necessarily sequential or hierarchical and can occur simultaneously (Klein et al., 2014). However, manifestation of adaptation (highlighted by Part D of Fig. 1 and elaborated in Section 2.4) is influenced by the above-mentioned factors. For example, water management organisations that possess a) enhanced knowledge, b) has planned measurable targets, c) guided by implementable goals e) for low-regret anticipatory measures f) led by visionary leaders that g) monitors its actions and iterates its implementation are successful in adaptation. This is highlighted by Part D of Fig. 1. The overall aim of adaptation is, of course, to reduce risks and vulnerability and maintain or improve the economic, social and environmental sustainability. These various strands of adaptation are further discussed in the following subsections to highlight existing information and understanding, and identify knowledge gaps.

Since the impacts of climate change will be experienced mainly through the medium of water, water organisations need to build adaptive capacity. However, adaptive capacity and adaptation barriers are closely related, with, for example, the lack of adaptive capacity components such as knowledge, economic and infrastructural resources and inadequate organisational mechanisms becoming barriers (Fig. 1 Part B & C). On the other hand, the availability of adaptive capacity in itself does not ensure the absence of adaptation barriers. Instead, the effective utilisation of adaptive capacity is reduced by barriers (Oberlack, 2016) such as cultural and normative behaviours, rigid and outdated laws, and bureaucratic procedures and inaccessibility to information among others. Adaptive capacity is utilised in an organisational context which is itself shaped by existing laws and implemented via a 'normative' procedure (although what is normative is questionable). In addition, the inherent uncertainty of climate change affects utilisation of adaptive capacity, such as when and where to apply financial and human resources. However, elements of adaptive capacity, such as the existence of a flexible organisational mechanisms, can overcome the challenges of uncertainty (Dessai and Hulme, 2009).

Inter-organisational networks enable decision makers and actors to acquire additional adaptive capacity from beyond the organisation (Baird et al., 2015; Bodin and Crona, 2009) to overcome barriers, and thus enable the translation of adaptive capacity into adaptation manifestation. The role of transboundary organisations (Sternlieb et al., 2013) in these networks is particularly important both for enhancing the adaptive capacity (Berkes, 2009) and also for reducing the adaptation barriers (Oberlack, 2016). Current literature regarding the relationship between a) adaptation enabling characteristics, b) adaptation barriers and c) manifestation of adaptation is fragmented. Fig. 1 above synthesises and illustrates the relationship between these three components for understanding adaptation. The Fig. 1 above outlines the various components of climate change adaptation and is not an indication of the process of adaptation because adaptation is iterative based on the experiences and information gained over time. As highlighted in Section 1, the impacts of climate change are mostly manifested through the medium of water, reducing its availability, increasing demand and flood risks and also affecting the quality of the available water. Information and knowledge regarding these impacts are necessary for creating awareness among policy and decision makers. The availability of technology, infrastructure, resources and organisational mechanisms enhances the adaptive capacity. However, availability of these determinants of adaptive capacity alone are insufficient to ensure successful adaptation. Agency related factors such as the cultural and normative behaviours of the agents, the organisational contexts in which the organisation operates such as rigid and outdated laws and lengthy bureaucratic processes, and inherent characteristics of climate change, such as uncertainty and other bio-physical features, can hinder the effective utilization of available adaptive capacity. Literature surveyed in Section 3.2 and 3.3 indicates the important role of inter-organisational networks and transboundary organisations in enhancing adaptive capacity as well as overcoming barriers. Finally, the visible characteristics of a well-adapting organisation are listed in the fourth component of the diagram in Fig. 1. The remaining part of this section draws out the key knowledge gaps based on the literature surveyed and discusses its implications.

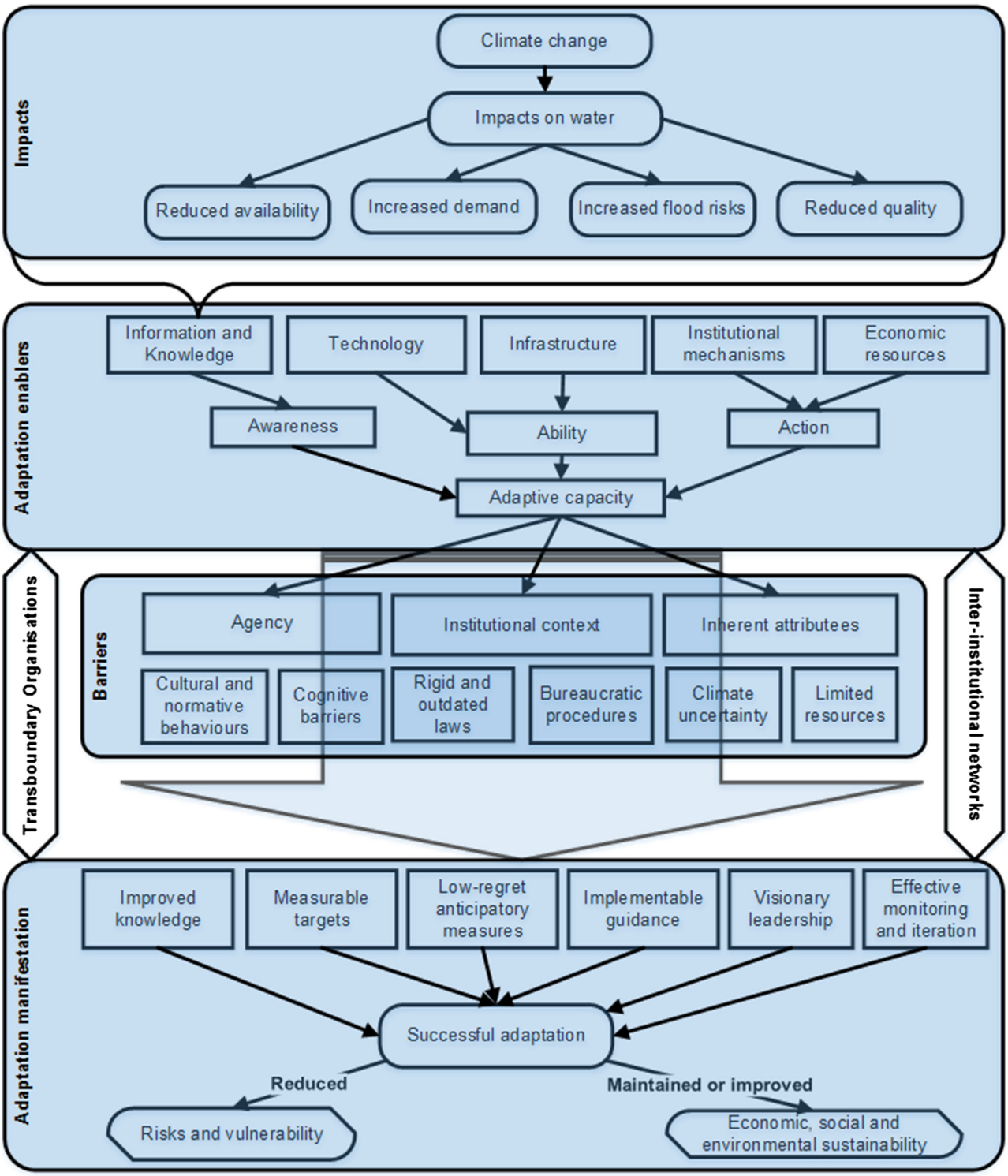


Fig. 1. Conceptual relationship between the key components of climate change adaptation.

4.1. Adaptation by organisations

Evaluations of adaptive capacity, particularly in developing economies, focus on communities but not on the organisations that administer water

The most important element in adapting water management to climate change – the water management organisations – is often ignored in the literature, particularly in studies of developing economies. It may be implicitly assumed that organisations which administer water for public good will adapt if the society or the sector as a whole adapts to the changing climate. However, organisations and agencies that are administering the ecological and societal needs of water will have to lead in adapting to the changes. Whilst research on adaptive capacity (for example, Pandey et al. (2011)) is emerging in the context of developing economies (Mertz et al., 2009), most studies focus on communities or the vulnerability of physical systems and rarely on the capacity of organisations which are expected to enable society (and ecology) to

adapt to the climate. Nevertheless, some key lessons on the characteristics of adaptation can be drawn from some of these studies.

Climate change adaptation consists of levels of actions to be undertaken by individuals for their own benefit or by the government organisations to protect its citizens (Adger et al., 2005) and often it requires collaboration between the two (Wamsler, 2016). For instance, adaptation actions by farmers can be seen as individual adaptation while adaptation in water management will be a mix of private and public (Mendelsohn, 2006). Wamsler, (2016) conjectured that public adaptation can support or obstruct individual adaptations. Adaptations oriented towards conservation of the environment are public and as it becomes more public it becomes more complex (Huitema et al., 2016). These actions take place within a hierarchical structure of different organisational bodies operating at different levels that interact, influence, enable or hinders the adaptation actions at another level (Adger et al., 2005; Lyle, 2015). The adaptation process (Arnell and Delaney, 2006; Berkhout, 2012; Grothmann and Patt, 2005) by organisations involves a) perception, b) evaluation, c) enactment, and d) feedback, which are not necessarily sequential but interactive and often reinforcing or constraining one another (Klein et al., 2014). Decision makers do not necessarily respond based on the 'true' level of risk inherent in the changing climate, and it may be not possible to determine the level of risks accurately in many instances due to the uncertainties in climate change, but adaptation strategies are planned based on the perceived risks (Burch and Robinson, 2007), which may be shaped by extreme weather events (Engle, 2013), potential threats (Halady and Rao, 2010; Marshall et al., 2013) and socio-cultural contexts (Mauelshagen, 2012). Therefore, understanding how key actors within water management organisations perceive risks is essential (Brown et al., 2013; Smith et al., 2014) for evaluating the ability and likelihood of the organisation to adapt to the changing climate. Evaluation of the adaptation options depends largely on the available economic, technological, and human resources available, besides political and cultural factors and may be evaluated differently by different actors (Arnell, 2011). It also is shaped by the cognitive capacity of decision makers (Grothmann et al., 2013) to articulate the resources requirement (Porter et al., 2015). On other hand, organisations or actors can also maladapt and thereby create unintentional and unforeseen vulnerabilities (Adger and Barnett, 2009; Juhola et al., 2016; Kiparsky et al., 2012). Juhola et al. (2016, p. 139) defined maladaptation as 'a result of an intentional adaptation policy or measure directly increasing vulnerability for the targeted and/or external actor(s), and/or eroding preconditions for sustainable development by indirectly increasing society's vulnerability'. Since adaptation is an iterative process, implementing the adaptation strategies and experiences gained through such implementations are important for improving future adaptation strategies (Berkhout, 2012). Understanding whether or not the water management organisations can reduce the likely impacts and/or take advantage of the new opportunities clearly becomes an important concern.

4.2. Adaptive capacity limitations

Evaluation of adaptive capacity and its application for policy making remains contested due to its latent, dynamic and contextual nature

Although consensus on the determinants of adaptive capacity is growing, its evaluation and application for policy making is contested. The generic determinants of adaptive capacity of Smit et al., (2001) continue to be the assessment framework in different contexts, sectors and scales of assessments. However, disagreements remain regarding the methods of data collection, assessments, and criteria to be used for measurement of adaptive capacity (Engle, 2011; Hinkel, 2011), due to the diverse and context-dependent nature of climate change vulnerability and risks.

Evaluation of adaptive capacity is challenging because of its latent and context specific nature and the influential role of dynamic variables (Juhola and Kruse, 2015). Determinants of adaptive capacity are difficult to generalise and do not carry equal weight between contexts (Engle, 2011; Pandey et al., 2011). Methods of adaptive capacity evaluation using aggregated indices (Gupta et al., 2010; Pandey et al., 2011) have been found to be of limited use due to the difference in context and subjectivity. Since adaptation to climate change is variable-rich, multidimensional and perhaps chaotic, a single approach is unlikely to understand different challenges (Biesbroek et al., 2013). Rigorous conceptual frameworks for evaluating the adaptive capacity of organisations are lacking as there remains contentions regarding the usefulness, transparency and objectivity of adaptive capacity indicators (Hinkel, 2011). Not only are the methods of evaluating adaptive capacity contested, but their applicability to policy making remains controversial, particularly the use of quantitative indicators (Hinkel, 2011). In addition, limiting analysis to determinants of adaptive capacity ignores other key factors such as adaptation barriers and is inadequate to understand why the availability of adaptive capacity is not an assurance that adaptation will occur (Burch and Robinson, 2007).

Since the availability of adaptive capacity in itself does not guarantee that adaptation will occur, research needs to progress to understanding how existing adaptive capacity can be utilised successfully and enhanced. This will require the factors, such as attitudes of actors, inherent uncertainty of climate change and organisational challenges, such as rigid and outdated processes of decision making, that contribute to the barriers to the utilization of adaptive capacity (Moser and Boykoff, 2013) to be understood and overcome to transform adaptive capacity into adaptation manifestation.

4.3. Adaptation manifestations are limitedly visible

The limited studies on the manifestation of adaptation are confined to industrialised countries and unlikely to have huge relevance for water management organisations in developing economies where public organisations administer water.

In spite of the growing efforts on adaptation, examples or empirical studies that demonstrate how water management organisations have actually adapted to the impacts of climate change are limited (Arnell, 2010; Mimura et al., 2014), especially in developing countries (Sud et al., 2015). Those reported (e.g. Gawith et al., 2009; Jude et al., 2017; Tompkins et al., 2010) are isolated and unlikely to be directly applicable to developing economies where the socio-cultural and economic contexts, in addition to institutional regulations and legislations of how water is governed and administered, are different. Moreover, as adaptation depends on risk perceptions and availability of resources and technology, socio-economic and cultural factors are likely to play a key role in how water organisations respond to similar or different impacts (Azhoni et al., 2017b). A challenge for climate change adaptation is to use an understanding of the drivers of past adaptation efforts to support its mainstreaming into other general developmental praxis (Mertz et al., 2009).

4.4. Need for identification of context to barriers

Few studies take into account the socio-cultural and economic contexts of adaptation barriers, and whilst their root causes and interrelationships are poorly understood.

The best top-down national or regional plans do not necessarily translate into successful adaptation (Preston et al., 2010) as adap-

tation is context specific and contingent upon factors including aptitude and attitude of implementing agencies towards risks (Wilby and Vaughan, 2011), political and circumstantial priorities (Haddad, 2005) and the availability of resources and technology. Moser and Ekstrom (2010) propose that working through barriers, rather than skipping entire phases of the decision process, will prove beneficial for the decision outcome. Therefore, exposing the factors that stop, divert or delay organisations to effectively adapt are crucial in the adaptation process (Berkhout, 2012).

Superficially, adaptive capacity and adaptation barriers appear as the mirror image of one another – the absence of adaptive capacity is a barrier. Although the absence of certain determinants of adaptive capacity, such as information and resources, lead to barriers their presence does not ensure that adaptation will occur (Moser and Boykoff, 2013). Therefore, determinants of both adaptive capacity and barriers have to be taken into context, although not necessarily as separate entities. Adaptation planning will require the identification of adaptation barriers, and an understanding of the factors that control their emergence and sustenance (Eisenack et al., 2014). Due to the contextual nature of barriers (Azhoni et al., 2017b; Eisenack et al., 2014) and their dependence on actors (Baker et al., 2012; Engle, 2012), defining and conceptualising the local causes of barriers remains challenging.

Although there is a growing interest in adaptation barriers in general, research on barriers for organisations to adapt is limited (Biesbroek et al., 2013), with few studies addressing the causes of barriers and the interdependences between them (Azhoni et al., 2017b; Eisenack et al., 2014). Moreover, knowledge on barriers to adaptation in developing economies remains scattered and barriers emerging from political, social and psychological factors are rarely mentioned (Shackleton et al., 2015). This is largely due to a lack of frameworks to understand the barriers (Biesbroek et al., 2013) as it is contingent upon the societal values (O'Brien, 2009) and attitudes towards risks (Adger et al., 2009) besides the physical and natural circumstances. Adger et al. (2009) contend that issues of values and ethics, attitudes to risks, knowledge, and culture construct the context of adaptation and hence barriers are mutable. Therefore, research on why barriers emerge and their interactions and compounded impacts that shape adaptation processes are urgently required (Shackleton et al., 2015).

4.5. Role of inter-organisational networks

Inter-organisational networks, particularly within public organisations and between governmental and non-governmental organisations, are poorly understood.

Increasing the adaptive capacity beyond the inherent capacity within an organisation requires acquisition of capacity from other organisations, which can be supported by transboundary organisations. Inter-organisational networks can exist vertically between organisations operating at different scales (Azhoni et al., 2017a), such as the national scale or more locally, or horizontally between organisations in various sectors (Azhoni et al., 2017b), as networks are expected to be 'self-organised' and not externally imposed (Leitner and Sheppard, 2002). The presence of a strong network among organisations can provide an opportunity for them to gather resources through the network even when the particular organisation does not possess the required resource to face the challenge (Ziervogel and Downing, 2004). Since effective networks enhance smooth adaptation (Lejano and Ingram, 2008), networking barriers become barriers for adaptation (Azhoni et al., 2017b; Burch, 2010; Vedeld et al., 2015).

Although inter-organisational networks between non-profit organisations have been shown to enhance adaptive capacity by creating an 'ecosystem of organisations' through sharing of knowledge and information (Steinberg, 2009), networks among public organisations remain unexplored. Public/government organisations tend to work in silos and not much attention has been given to how effectively services can be delivered through improved coordination (Azhoni et al., 2017a). Organisations are more complex than individuals (Pahl-Wostl, 2009), so that social network theories of individuals cannot be directly applied. Moreover, the existence of social networks in themselves cannot be assumed to enhance the adaptive capacity of an organisation (Brockhaus et al., 2012) if the network is exclusive and rigid, leaves conventional wisdom unchallenged and does not enable learning (Newman and Dale, 2007).

4.6. Transboundary organisations and their role in enabling adaptation

The role of transboundary organisations in enhancing the adaptive capacity of water organisations is poorly understood and hence underappreciated.

The role played by transboundary organisations in supporting organisations to adapt needs to be recognised and supported (Griggs and Kestin, 2011; Mastrandrea et al., 2010; McKenzie Hedger et al., 2006; Tompkins et al., 2010). Such transboundary organisations enhance adaptive capacity by bridging the gap between researchers and policy and decision makers through providing or enabling them to acquire the necessary resources or to create a system conducive for adaptation (Eisenack and Stecker, 2012). Additionally, transboundary organisations can play the crucial role of advocacy that provides a stimulus towards adaptation and change. Actions such as the development of adaptation techniques, building knowledge capacity and developing knowledge regarding vulnerable systems to support decision makers to take adaptation measures, which are considered as adaptation facilitation, can be enhanced by transboundary organisations. The role of such organisations in developing economies is inadequately assessed and hence is poorly appreciated.

5. Conclusions

The importance of adaptation, particularly for water management, is widely recognised. Gaining a consensus regarding generalised methods of adaptive capacity evaluation and application to policy is unlikely because of its latent, dynamic and contextual nature, even though its determinants are more or less recognised. Therefore, studies focusing on the existence of 'adaptation attributes' and 'adaptation readiness', particularly using qualitative approaches to capture the contextual nuances, are emerging primarily from industrialised countries but are unlikely to have huge relevance for developing economies where climate adaptation has to compete with other developmental priorities. The need for adaptation at all scales, taking into consideration both top-down and bottom-up perspectives, is widely emphasized in literature. However, the flows of knowledge and resources from higher levels of government through cross-scale networks that shape the temporal dynamics of climate adaptation are inadequately studied to understand how socially equitable and sustainable adaptation to climate change can be enhanced. Given that climate change impacts and adaptive capacity vary between sectors, actors and regions, local studies are required to draw out contextual perspectives on adaptation in order to complement national adaptation policies. In this regard, transboundary organisations that operate across scales and sectors have the potential to enhance the adaptive capacity of water organisations. This can be complemented by improving inter-organisational networks because social networks among actors can be key to acquiring adaptive capacity from

beyond the organisation. Organisations are more complex than individuals, and hence, social network theories of individuals cannot be directly applied and hence network theories should be applied cautiously. Further, the existence of social networks in themselves cannot be assumed to enhance the adaptive capacity of an organisation if the network is exclusive and rigid, leaving conventional wisdom unchallenged and preventing learning. As such, understanding the factors that hinder inter-organisational cooperation by taking into account specific contextual socio-economic and political factors will support identifying and overcoming adaptation barriers.

In spite of the growing initiatives on climate change adaptation, defining successful adaptation and discerning the relationships between intentions, strategies, actions, and outcomes remain a challenge. Adaptation tracking is particularly challenging due to inconsistencies regarding what actually counts as adaptation actions and what counts as adaptation preparation. Models of successful adaptation for water management are limited; due to the inter-sectoral nature of water management, inherent uncertainties in climate change, scale issues and the continuous ongoing nature of adaptation. Since adaptation is a continuous process, as new challenges emerge, questions of what actually counts as successful adaptation remains.

The literature reviewed here provides rich insights into understanding adaptation-enabling characteristics and barriers. However, the existing studies are inadequate to draw conclusions on the inter-relationship between adaptive capacity, adaptation barriers and manifestation of adaptation attributes. The relationship between the various determinants of adaptive capacity and the various types of barriers and how they emerge and are sustained is inadequately evidenced by empirical studies. As issues of values and ethics, attitudes to risks, knowledge, and culture construct the context of adaptation, research on why barriers emerge and their interactions and compounded impacts that shape adaptation processes are urgently required. Addressing these knowledge gaps will help to improve the designing of adaptation strategies, thereby improving the ability of water organisations to address the ongoing challenges of climate change.

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