Reg Environ Change (2016) 16:2409–2418
DOI 10.1007/s10113-016-0965-8

ORIGINAL ARTICLE

Adapting drinking-water systems to coastal climate change: evidence from Viet Nam and the Philippines

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Received: 23 October 2015 / Accepted: 29 March 2016 / Published online: 20 April 2016

Abstract Coastal areas will increasingly experience adverse climate hazards such as coastal flooding and severe storms as a result of climate change. These hazards adversely affect drinking-water systems and thereby reduce access to safe drinking-water. Effective adaptation implementation minimizes the damaging impacts of these hazards. However, research on the enablers of and barriers to effective adaptation in low-income countries is lacking. This study maps enablers and barriers to climate change adaptation of water systems in coastal low-income countries using evidence from Viet Nam and the Philippines, countries which experience frequent extreme climate events. Interviews were carried out with staff from 29 water utilities and government agencies. A systematic framework for diagnosing barriers to climate change adaptation was used to analyze the responses. Five factors were identified as relevant to effective adaptation: partnerships; financial resources; human and technical resources; leadership and political will; and awareness of climate change. The factors identified were related to all the elements of the framework—actors, system of concern, and context—and were relevant to the three phases of the adaptation process (understanding the problem, planning the adaptation, and managing the implementation). Our findings can assist water system managers in diagnosing barriers to effective adaptation that may exist and identifying relevant partnerships and resources that will aid in overcoming these barriers.

Keywords Drinking-water · Adaptation · Barriers · Low-income

Introduction

In its Fifth Assessment Report (AR5), the Intergovernmental Panel on Climate Change (IPCC) states that "coastal systems and low-lying areas will increasingly experience adverse impacts such as submergence, coastal flooding, and coastal erosion" (IPCC 2014, pp 17). Coastal areas are particularly important because of their economic significance and high population. Three quarters of all large cities are located on the coast, and more than 40% of the global population resides within 100 km of the coast (UNEP 2005; UN, n.d.). The large population and high urbanization of these regions cause land cover change, which reduces the coastal environment resilience to climate hazards (Lambin et al. 2001; USGS 1999). For example, filling in wetlands for infrastructure development reduces the flood control ability of the environment. Coast-specific hazards, such as sea-level rise, make these areas particularly vulnerable to the changing climate (EPA 2015). Coastal climate hazards, such as coastal erosion and sea-level rise, damage infrastructure like drinking-water systems and cause salinization of drinking-water sources. Impacts on drinking-water systems include pipe breakage, system flooding, water source contamination, and power outages which hinder power-dependent pumping and

Editor: Ülo Mander.

Electronic supplementary material The online version of this article (doi:10.1007/s10113-016-0965-8) contains supplementary material, which is available to authorized users.

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treatment, all of which reduce the quality and/or access to drinking-water among the supplied population.

According to the WHO and UNICEF Joint Monitoring Programme (JMP), more than 650 million people lack access to improved drinking-water sources, most in low-income countries (WHO and UNICEF 2015). In 2012, approximately 842,000 diarrheal deaths resulted from inadequate water, sanitation, and hygiene practices worldwide, including approximately 380,000 children under the age of five (Prüss-Üstün et al. 2014). With the impacts climate hazards could have on drinking-water quality through water contamination from floods, these numbers could increase, especially since only a few drinking-water technologies are resilient to climate change (Howard et al. 2007). Consuming unsafe water also has adverse effects on school attendance and economic development, as illnesses like diarrhea lead to high rates of school absenteeism and increased expenditures on health care (Hutton and Haller 2004; Monse et al. 2013). Lack of access near the home increases time spent collecting water which contributes to decreased school attendance (Sorenson et al. 2011). In addition to lower access to improved drinking-water sources, low-income countries have a higher likelihood of water system damage by climate hazards because of insufficient resources to adapt to and cope with these hazards. Adaptation is the process of adjustment of systems to actual or expected climate and its effects in moderating harm or exploiting benefits (IPCC 2014). According to the IPCC AR5, "analysis and implementation of coastal adaptation has progressed more significantly in developed countries than in developing countries towards climate resilient …coasts." (IPCC 2014, pp 365)

To minimize the adverse impacts of climate hazards on drinking-water systems, effective adaptation should be employed. Additionally, as access to improved drinking-water sources is increased in low- and lower middle-income (LLMI) countries, water utilities may benefit from incorporating climate change into newly established systems to minimize costs of retrofitting systems in the future. However, the barriers to adaptation may delay adaptation. Biesbroek et al. (2011) note the importance of understanding barriers to adaptation to ensure effective implementation. However, there is limited research on enablers and barriers in LLMI countries. Most of the literature focuses on high-income countries (examples include Bierbaum et al. 2012; Hunt and Watkiss 2011; Jantarasami et al. 2010; Lawrence et al. 2015; Measham et al. 2011). With the impacts climate change will have on LLMI countries, more research should be carried out because almost half of the world population (approximately 3.45 billion people) resides in LLMI countries (World Bank 2015).

In light of the above mentioned, this paper assesses the enablers and barriers to climate change adaptation in coastal areas of LLMI countries, with evidence from Viet Nam and the Philippines. Because of the limited understanding of why these enablers and barriers exist, this study also explores some of the reasons for the existing factors.

The extensive coastal areas of Viet Nam and the Philippines make these countries vulnerable to coastal climate hazards. They are hit by numerous storms annually that cause extensive damage. Typhoon Haiyan, which hit the Philippines in 2013, affected over 16 million people and was one of the top ten most disastrous storms for the 1900–2014 period, in relation to the number of people affected (EM-DAT 2014). According to the IPCC (2014), Viet Nam is one of the top five nations by population in coastal low-lying areas.

For this study, barriers to adaptation are defined as "those factors that actors experience as impeding the process of developing and implementing adaptation" (Biesbroek et al. 2011). Enablers are those factors that facilitate this process. Enablers and barriers to adaptation were determined through interviews with government officials and water utility personnel in Viet Nam and the Philippines. A framework developed by Moser and Ekstrom (2010) for diagnosing barriers to climate change adaptation was used to analyze the responses from interviews. While Moser and Ekstrom's work addresses barriers to climate change adaptation, here we address both enablers and barriers as factors that influence adaptation.

Study results add valuable information to the evidence currently available on implementing adaptation in LLMI countries. It will aid water system managers in determining the kinds of resources that will facilitate effective adaptation.

Methods

Study participants

Study participants were water utility personnel and government officials involved in climate and/or water programs in Viet Nam and the Philippines. Purposeful sampling—sampling information-rich participants—was used to select participants. Opportunity sampling, using information from a study participant to inform selection of additional participants, was also used. Participants were recruited through personal contacts in UN agencies, government agencies, and water utilities. This study received an IRB exemption from the University of North Carolina at Chapel Hill, IRB #14-0725.

Interview guide development

The interview guides (Online Resource 1) were developed after a review on climate change in coastal areas and corresponding effects on drinking-water systems. This review aided in identifying the relevant hazards for coastal areas, which helped in determining what questions should be posed. One major source of information was the Contribution of Working Group 2 for the IPCC Fifth Assessment Report, which provides information on impacts of climate change and climate hazards in coastal areas.

Questionnaires administered to water utility personnel and government officials differed slightly in content. Questions specific to drinking-water systems, such as system types, were asked of water utility personnel but not government officials. In addition to basic participant information, like organization and city, information on climate policies and enablers and barriers to adaptation was collected. All questions were open ended. The interview was pilot tested with a postdoctoral researcher with experience in developing and evaluating technologies for low-cost water treatment and safe water access. Piloting aided in refining the questions; potentially leading questions were rephrased, and close-ended questions were changed to open-ended questions to avoid forcing answers.

Data collection

Data were collected through interviews or paper-and-pen survey. Interviews were semi-structured and recorded. The survey content was identical to the interview guide. The conversational form of the interview allowed respondents to expand on their responses, which was not possible with the paper-and-pen survey. Interviews were conducted over the course of 3 weeks (August 3–23, 2014) in the Philippines and 4 weeks (August 25–September 20, 2014) in Viet Nam.

Twenty-six interviews were carried out, and three pen-and-paper surveys were completed. Eight interviews and surveys were administered to water utility personnel and twenty-one to government officials (Table 1). Sixteen interviews were conducted in Viet Nam and 13 in the Philippines.

Interview analysis

Interviews were transcribed and analyzed using inductive coding, which involves analyzing the transcript to identify patterns and themes. Responses from the survey were similarly coded. Interview coding was carried out in Atlas.ti 7. These codes represent factors and sub-factors that influence effective adaptation implementation. In addition to the factors identified, reasons for the enablers and barriers noted were extracted from the responses. The frequency of identification for each factor was determined based on the number of respondents that identified at least one sub-factor. Each factor is counted once for a respondent regardless of how many sub-factors are identified by that respondent. Therefore, the total counts for sub-factors within a factor may exceed the counts for the factors.

Table 1 Study participants by country and organization type

Organization	Country		Total
	Viet Nam	The Philippines	
Water utility	3	5	8[a]
Government agency	13	8	21
Total	16	13	29

[a] Three of these completed pen-and-paper surveys

Framework and hypothesis

Moser and Ekstrom (2010) developed a framework (Fig. 1) to comprehensively diagnose barriers to climate change adaptation, and this was used to frame factors identified from interviews. The framework has three interacting structural elements: the actors directly or indirectly involved in the adaptation process, the larger context within which these actors perform, and the system of concern upon which they act. Based on the framework, we hypothesize that each of the structural elements of the framework will be relevant to at least one identified factor.

One goal of the Moser and Ekstrom framework is to aid in effective decision making and as such is embedded within three common phases of a decision-making process: (1) understanding the problem at hand; (2) planning possible adaptation options; and (3) managing adaptation implementation. With each phase, the Moser and Ekstrom framework is applied to produce a comprehensive analysis of enablers and barriers to adaptation. This framework was used because it offers a systematic approach to analyzing factors relevant to adaptation and takes into consideration social and physical systems that may influence decision making.

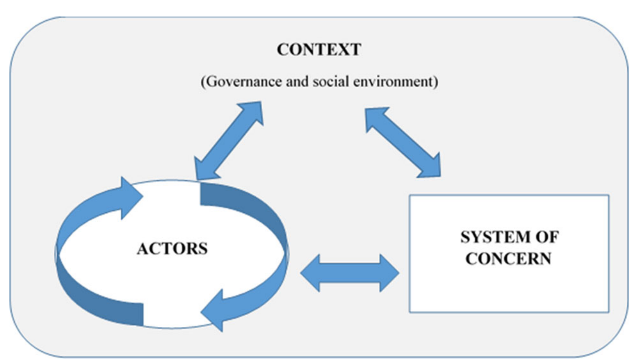

Fig. 1 Structural elements of the framework. This framework has been modified for this study from a barrier diagnostic framework developed by Moser and Ekstrom (2010)

Results

Identified factors relevant to water system adaptation to climate hazards

Four barriers were identified by the respondents: insufficient funding, lack of political will and poor leadership, lack of climate change awareness, and inadequate human and technical resources (Table 2). One enabler—partnerships—was identified (Table 2). The reasons for these factors, identified by respondents, are also presented in Table 2. These enablers and barriers were renamed into neutral factors. For example, insufficient funding was renamed financial resource availability. The factors identified were financial resource availability, human and technical resource availability, climate change awareness, partnerships, and leadership and political will. Each of these factors was identified by both government officials and water utility personnel. These factors had sub-factors identified during the interviews that helped explain different features of the factors.

Partnerships include partnerships between stakeholders as well as in information sharing. Included are partnerships with local people, across different levels of government, and inter-sector collaboration. This factor was identified 24 times. Sharing information between developed and LLMI nations was mentioned 10 times.

Financial resource availability refers to the availability of financial resources to implement effective climate change adaptation. This factor was identified 24 times. This factor comprises resources for training, for making changes to water systems, and for carrying out environmental management practices to protect water systems.

Human and technical resources refer to the availability of staff as well as the ability of staff and other stakeholders to carry out activities related to adaptation. It also includes the availability of technical resources such as climate prediction tools to ensure appropriate adaptation activities are carried out. Overall, this factor was identified 22 times. Available human resources were identified 9 times, human technical capacity was identified 15, and availability of technical resources was identified 18 times.

Leadership and political will refers to the willingness and ability of those in leadership to deal with climate change issues as well as the policies they put in place to aid in adaptation. It includes leadership by the government as well as water system managers and the internal and external policies that guide water utilities. This factor was identified 16 times. Political will was identified 6 times, favorable policies 13 times, and leadership 9 times.

Awareness of climate change refers to the awareness of local people, governments, water system personnel and other stakeholders about climate change and its impacts on the population, environment and water systems. This factor was identified 8 times.

Table 2 Identified factors relevant to climate change adaptation

Identified Factors		Reasons factors are relevant
Factors	Sub-factors	
Partnerships (24)	Partnerships with local people	Cross-cutting influence of climate change on different sectors
	Partnerships with international organizations and high-income countries	
	Inter-sector collaboration	
	Sharing lessons	
Financial resource availability (24)	Financial resources of the government	Competing priorities
	Financial resources of water corporations	
	Financial resources of water consumers	
Human and technical resource availability (22)	Available staff	Uncertainty in climate projections
	Human technical capacity	
	Technical resources for climate and impact projections	
Leadership and political will (16)	Political will	Distant timeframe of climate projections; Uncertainty
	Favorable policies of on climate change	
	Leadership and management of water system managers	
Awareness of climate change (8)	Awareness of local people, government, and water system personnel	Competing priorities with more certain impacts

Numbers in parentheses represent the number of respondents that identified factors

Framing factors within the barrier identification framework

Three structural elements of the framework—actors, context, and system of concern—influence the implementation of adaptation based on the Moser and Ekstrom framework. Table 3 shows the types of actors and specific social and political environments (contexts), based on respondent responses, that are relevant to each of the factors presented in this section. The system of concern was not specific to the factors; it spanned across all factors because it represents the system for which adaptation is being considered.

Moser and Ekstrom (2010) also show that factors influence adaptation at the different phases of the decision-making process: understanding the problem, planning the adaptation, and managing the implementation. Responses from the interviews show that each of the factors identified are relevant at specific phases of the decision-making process, with some factors being of importance in two or more of the phases. A correlation between the factors and each of the phases was made for all but one of the factors (Table 4).

Discussion

Factors relevant to effective climate change adaptation of drinking-water systems

The factors are discussed below within the context of the decision-making process described in the Moser and Ekstrom (2010) framework.

Partnerships

Partnerships promote understanding of the problem by creating awareness of climate change and its impacts on water systems among stakeholders. Collaboration between climate scientists and water system personnel improves knowledge of climate projections and impacts on the system. Additionally, failing to form the required partnerships may lead to ineffective and, possibly, counterproductive adaptation actions (Adger et al. 2005). Respondents noted that policies that established inter-sectoral committees aid in improving understanding about climate change. One noted "climate change is a multi-sector issue, so nobody can be an expert for one sector and also for other sectors. That is why with the steering committee we invite people from different sectors and so we have a better discussion, better opinions in terms of climate change and its impacts." By ensuring that stakeholders from different sectors collaborate, diverse views are introduced, increasing the likelihood of comprehensive adaptation and reducing the risk of adaptation actions in one sector causing harm in another (Kates et al. 2012; Archie 2014).

Partnerships are also relevant for planning and managing adaptation. Adaptation should not be carried out as stand-alone activities but rather be incorporated into existing cultural practices (Adger et al. 2013). Respondents noted that indigenous knowledge is beneficial to effective adaptation. Nyong et al. (2007) found that in the African Sahel, a region characterized by frequent droughts, local populations developed adaptation options, such as implementing different cropping patterns, that aided in reducing their vulnerability to climate variability. Indigenous practices are a major resource for adapting to climate change

Table 3 Fitting the structural elements of the Moser and Ekstrom (2010) framework into the factors identified by respondents

	Actors	Context	System of concern
Partnerships	Water system personnel; local people, government officials; stakeholders from water-related sectors; international organizations	Collaborative environment with governments	Drinking-water infrastructure and water source
Financial resource availability	Water utilities; government officials; local people	Government revenue for climate change; private sector investments; aid (foreign partners and international organizations).	
Technical and human resource availability	Water system personnel; climate change educators and trainers; government officials	Public and private workforce	
Leadership and political will	Water system managers; government officials	Favorable policies for climate change adaptation	
Awareness of climate change	Water system personnel; government officials; and local people	Social norms, culture, education	

Table 4 Relevance of each factor throughout the decision-making process

	Understanding the problem	Planning the adaptation	Managing the implementation
Partnerships	Knowledge transfer from climate researchers to water system personnel and government officials	Collaboration between water system personnel and other stakeholders[a] to decide on adaptation options	Partnerships with other actors that make use of the water sources to improve implementation success
Financial resource availability	Financial resources for investment in climate projections and impacts research.	Prioritizing different adaptation options in addition to other development initiatives based on limited funds	Resources to produce desired outcomes in government and water utility strategies
Technical and human resource availability	Scientific knowledge about climate projections and impacts on water systems	Ability to select and prioritize effective adaptation based on technical knowledge of systems	Available and knowledgeable staff to carry out selected adaptation options
Leadership and political will	Leadership to improve knowledge of stakeholders, through educational policies and making workshops available for technical staff	Presence of leadership to select and prioritize options effectively	Government and water utility leadership to facilitate effective adaptation
Awareness of climate change	Presence of awareness campaigns to improve understanding of the problem and sensitize people to impacts	No correlation made	No correlation made

[a] These stakeholders generally include actors that make use of same water sources as utilities

(IPCC 2014). One reason for this is that indigenous people have a history of adapting to highly variable ecological conditions. However, the importance of this type of knowledge will be challenged by climate change impacts, particularly the increase in the frequency of extreme events (IPCC 2014). By fostering partnerships that combine science and technology with indigenous knowledge, robust solutions can be developed.

Jantarasami et al. (2010) conclude that, since the efficacy of adaptation is dependent on local climate impacts, a one-size-fits-all approach is inappropriate and establishing a system for sharing lessons will aid in effective decision making. Based on this, indigenous knowledge may not be appropriate in every situation because of varying social contexts. In addition to using indigenous knowledge, respondents noted that partnerships with international organizations and high-income countries are important and were a recurring theme in the interviews. There was a general understanding that contexts would differ and so adaptation would have to be appropriately modified; however, these lessons would still be valuable. By sharing these lessons, new solutions to deal with issues can be explored and mistakes made can be avoided.

Financial resource availability

Financial resources are necessary to (1) conduct research on climate projections and impacts to improve understanding; (2) aid in prioritization and assessment of all possible adaptation options to ensure effective planning; and (3) implement, monitor, and evaluate adaptation options. Many studies identify financial resource availability as a factor in climate change adaptation (e.g., Ford and King 2015; Archie 2014; Marshall and Stokes 2014; Antwi-Agyei et al. 2012; Gero et al. 2012; Huang et al. 2011; Jantarasami et al. 2010**)**. In LLMI countries, other priorities sometimes dominate investment, leaving little funding for climate change adaptation (Biesbroek et al. 2013). According to a respondent, “a challenge [to adaptation] is the lack of resources because in order to build the dike or the river bank and some other works in the remote areas, it costs a lot of money. So we let go of the funding for that [adaptation] in order to do all the work needed in the critical areas.”

Resources identified by respondents include those of the government to support water utilities, resources of the utilities to ensure continued and safe water supply during and after disasters, and resources of consumers to make payments to keep systems functioning. Financial resource availability is relevant for LLMI regions because financial investments in infrastructure, training, and other requirements are sometimes lacking for the everyday maintenance of systems in the absence of climate change concerns. Prioritizing climate change impacts is, thus, not always a consideration. “It is known that the impact of climate change is long term and it is not what we see right now so it does not concern seriously the policy-makers and responsible agencies. This causes a lot of difficulties and challenges during the implementation process on issues such as the distribution of resources,” noted a respondent. Availability of financial resources needs to be coupled with effective use of these resources to promote the implementation of effective adaptation. Burch (2009) noted that "addressing a lack of … financial… resources is less a matter of creating more capacity than of facilitating the effective use of existing resources." Countries, therefore, need to be aware of where finances should be invested, whether it be in improving climate change knowledge or carrying out mitigation and/or adaptation activities, and in what ways to ensure effective adaptation.

Human and technical resource availability

According to Jantarasami et al. (2010) and Archie (2014), implementation of adaptation is hindered by limited technical information on climate change projections and impacts. This has brought about the concept of "no-regrets" adaptation, that is, options that, even in the absence of climate change, will provide net societal benefits (Bapna and Mcgray 2009). Some examples of this include improving management services and promoting resilient technologies (EPA 2012; Howard et al. 2007). Even with no-regrets options, there is hesitation to invest in adaptation. "Climate change impacts are long-term. We are not fully aware what the future challenges will be" stated one respondent. The uncertainty inherent in projections makes investment in adaptation difficult as policy makers are more concerned with short-term and certain challenges. Biesbroek et al. (2013), in a systematic review of barriers to climate change adaptation, found that only three were specifically climate change related, one of which was the uncertainty of climate change. Several models for predicting climate change effects have emerged to reduce the uncertainties in climate science (IPCC 2013). As model development continues, stakeholders would benefit from increased awareness of and investment in no-regrets adaptation since this is beneficial even in the absence of perfect climate models. This will also ensure timely adaptation is carried out, instead of leaving systems with no modifications to management and/or technology. The negative impacts of climate hazards can, therefore, be reduced with no-regrets adaptation.

With regard to human resources, respondents noted high turnover rates among staff because of a lack of incentives, particularly salaries. A respondent stated "for more than 10 years, the cost of living allowance has remained at 2000 Philippine Pesos per month. To reduce them leaving, maybe increase this or the salary. Employees on contract have no cost of living allowance and so no incentives to stay." Additionally, respondents noted that human technical capacity needed to be increased and can be done by adding climate change to the school curriculum. Due to the distant time frame of some adaptive needs, capacity building efforts among youths may be an effective use of resources. It will ensure they are trained before they become decision makers, especially if education occurs in climate change-related fields. According to UNICEF (2012), quality education on climate change is a key factor in ensuring that the skills necessary to adapt livelihoods to a changing environment are realized. Carrying out non-formal educational programs such as after-school activities that provide opportunities for research projects and internships engages youths in climate change issues. However, adding climate change to the school curriculum may overload curricula so it is important that the most appropriate issues are identified (UNESCO 2012).

Leadership and political will

Political will and policies for actions will aid in planning and implementing adaptation (Dannevig et al. 2013; Archie 2014; Ford and King 2015). According to Biesbroek et al (2011), governments can support adaptation by developing and providing frameworks for action, creating awareness about climate change, and encouraging adaptation practices. One respondent stated "[Climate change] laws sparked a lot of activity, helped in planning for disasters and creating supportive local governments." Respondents noted that, although some regulations have helped in bringing adaptation to the front of national agendas, additional policies can be put in place to further facilitate adaptation. A respondent stated "in recent years awareness has increased and [climate change] has gained more attention from government agencies. Climate change plan is getting more support." If regulatory mandates that support adaptation efforts are absent or inadequate, as is sometimes the case, overcoming barriers that arise from limited capacity becomes more difficult (Few et al. 2007; Fünfgeld 2010). According to a respondent, the "distant timeframe of climate change impacts makes government agencies focus on the 'right now' problems." There is, thus, a need for better communication of these impacts to those in leadership. Integrating climate change adaptation programs in national disaster risk reduction agendas can aid in ensuring that vulnerabilities of systems are reduced (Anderson 2012; Baker et al. 2012).

Water utilities are guided by policies of local, state, and national governments as well as their own internal policies. Respondents noted that willingness and determination of water utility leaders facilitate adaptation actions. To generate this determination, awareness activities for the heads of water corporations need to be carried out, according to respondents. One respondent noted that poor management can be seen in attempts to carry out too many activities that are not executable as a result of insufficient human and financial resources. Prioritizing activities ensures that whatever programs are carried out, even if few, are executed well. Based on these observations, in addition to training of water utility personnel, training of managers and government officials is also needed to aid in development and implementation of appropriate programs and policies.

Awareness of climate change

The significance of lack of awareness of climate change lies in its influence over some of the aforementioned and discussed factors. For example, poor awareness of the problem will lead to limited investments in solutions and to weak management and leadership of adaptation programs. According to a respondent, "awareness and policy have gained more attention from management and climate change is getting more support from organizations."

In the adaptation decision-making process, awareness of climate change is relevant to *understanding the problem*. Studies have found that by increasing awareness of the climate change problem, policy makers, the public, and other stakeholders become engaged and resources to find solutions (Hamin and Gurran 2015). Respondents noted that people cut down trees for income and by raising awareness about climate impacts and providing incentives, reduction in tree cutting was observed. This is supported by outcomes from the Noell Kempff Mercado Climate Action Project. According to the Nature Conservacy (2009), deforestation was reduced in the park and alternative economic opportunities for the local population was provided along with provision of basic services such as health and education. Awareness is, thus, one of the foundational barriers to climate change adaptation and has been found in several studies to be an important barrier to adaptation (Antwi-Agyei et al. 2013; Biesbroek et al. 2011, 2013, Moser et al. 2008; Watts et al. 2014).

Glavocic (2015) stated that "knowledge and understanding about adaptation is constrained by the complexity of climate change." To increase awareness, effective communication is, thus, necessary. Studies have shown that individuals view problems through preexisting beliefs, norms, and experiences (Kahan and Braman 2006, Kahan 2010; Nielsen and Reenberg 2010). By knowing and understanding the recipients of the information, information generators and communicators are able to deal with whatever values and beliefs influence how the recipients perceive and interpret the information and what specific concerns they have (Moser and Ekstrom 2010).

Why barriers exist

An analysis of the responses from the interviews revealed that the main reasons why barriers exist include: the distant time frame of climate change projections, uncertainty inherent in climate change projections, and competing priorities. One respondent stated that "for climate change adaptation, it is a long-term vision and there is no idea what challenges may come." LLMI countries are faced with challenges, such as food insecurity, inadequate public infrastructure, and poor health and education services, many of which have immediate consequences that are well understood. The better understanding of other national and local problems can move climate change down the list of priorities. Increasing information on the links between climate change and other priorities like water quality and quantity, inequality challenges, and food availability will aid in facilitating adaptation programs. This is important for LLMI countries because, according to the UNDP (2011), climate change impacts could reverse decades of human development gains.

Equality in the face of climate change

One recurring theme during the interviews was equality in the face of climate change. Interviews revealed areas of inequality in the absence of climate change as well as ways in which the changing climate could cause greater inequality. Respondents noted that capacity to deal with climate change is high in many areas relative to other areas, depending on available finances and geographic location. One respondent stated that, "provinces that are able to get funding deal better with climate hazards while poorer provinces do not." People who live in mountainous and/or remote areas are less likely to regain access to safe water after climate hazards, due to increased funding needed to provide service to these areas and high transportation costs.

With the changing climate, water utilities have the added challenge of having to balance extending service to unserved areas and maintaining and adapting existing infrastructure to strengthen resilience against climate hazards. If not maintained, the system would be susceptible to climate change hazards (WHO 2009). However, extending service ensures that people without access gain access. Extending services generally requires substantial financial investment, investments that are not as substantial for system adaptation. Water suppliers may have to consider innovative financing mechanisms to ensure access is increased and adaptation of existing systems is carried out to ensure existing supplies are not compromised.

Study limitations

This study relied on interview responses. Respondents could have identified enablers and barriers as responsible for outcomes for which they were not. Interviews in LLMI countries in other regions of the world would have allowed for a more comprehensive analysis of enablers and barriers relevant in the LLMI country context.

Conclusion

Five factors relevant to the effective implementation of adaptation of drinking-water systems were identified: partnerships; financial resource availability; human and technical resource availability; leadership and political will; and awareness of climate change. These factors span socioeconomic, political, and technical areas, showing the need for collaboration between different groups of actors and the relevance of context within which adaptation is being implemented. Results support the hypothesis that actors, the context within which they work, and the system of concern for which adaptation is being planned would be relevant to the enablers and barriers identified. We identified specific actors relevant to each factor. By knowing these actors, the right type of partnerships can be formed, when needed, to facilitate adaptation. The framework also aided in understanding how the factors fit into the phases of decision making: understanding the problem, planning the adaptation, and managing the implementation. By viewing these factors in these phases, effective solutions to barriers can be better determined and implemented.

Results from this study can aid relevant stakeholders in understanding some of the challenges to climate change adaptation in LLMI countries. By identifying some of the reasons why barriers exist—distant time frame of climate change projections, uncertainty in climate change projections, and competing priorities—water utilities and governments can focus resources on dealing with the root cause of the barriers, while facilitating enablers.

Acknowledgments This study was made possible through support of the Climate Change Resilient Development project, United States Agency for International Development (USAID)—Grant Number CCRDACD0006. The opinions expressed herein are those of the authors and do not necessarily reflect the views of USAID. We thank all interviewees; this project was possible because of their willingness to share their experience and knowledge with us. We also thank everyone who assisted with the fieldwork logistics.

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