



Adapting water management to climate change: Institutional involvement, inter-institutional networks and barriers in India



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ABSTRACT

The capacity of a nation to address the hydrological impacts of climate change depends on the institutions through which water is governed. Inter-institutional networks that enable institutions to adapt and the factors that hinder smooth coordination are poorly understood. Using water governance in India as an example of a complex top-down bureaucratic system that requires effective networks between all key institutions, this research unravels the barriers to adaptation by combining quantitative internet data mining and qualitative analysis of interviews with representatives from twenty-six key institutions operating at the national level.

Institutions' online presence shows a disconnect in the institutional discourse between climate change and water with institutions such as the Ministries of Water Resources, Earth Sciences and Agriculture, indicating a lesser involvement compared to institutions such as the Ministries of Finance, External Affairs, Planning Commission. The online documents also indicate a more centralised inter-institutional network, emanating from or pointing to a few key institutions including the Planning Commission and Ministry of Environment and Forests. However, the interviews suggest more complex relational dynamics between institutions and also demonstrate a gap between the aspirational ideals of the National Water Mission under the National Action Plan on Climate Change and the realities of climate change adaptation. This arises from institutional barriers, including lengthy bureaucratic processes and systemic failures, that hinder effective inter-institutional networks to facilitate adaptation. The study provides new understanding of the involvement and barriers of complex multi-layered institutions in climate change adaptation.

1. Introduction

Climate change is likely to affect the spatio-temporal distribution, availability and demand for water (IPCC, 2014) through changing precipitation (Chou et al., 2013) and evapotranspiration patterns, glacier melt rates (Jiménez Cisneros et al., 2014) and saline intrusion of coastal aquifers (IPCC, 2014). Water institutions – government ministries, departments and agencies, non-governmental and developmental agencies, and research and academic institutions – need the ability to anticipate and alleviate these potential threats in order to minimise vulnerability and damages (Bohensky et al., 2010; Matthews and Sydneysmith, 2010), while also taking advantage of the opportunities afforded by adaptation (IPCC, 2007; Vincent, 2007) and from complementing ongoing mitigation efforts (IPCC, 2014; Simonet and Fatorić, 2015). Although informal institutions, such as the ways in which societies interact, also play an important role in climate change adaptation (Berman et al., 2012), formal institutional bodies (particularly government institutions which have their mandate enforced by

legislation) play a major role in the allocation of resources, delineating responsibilities between actors, facilitating actions and mediating trade-offs (Cook et al., 2010). Hence, they are at the very heart of how the challenges of climate change will be addressed (Cook et al., 2010).

In addition to the availability of infrastructure, resources and technology (Arnell and Delaney, 2006; Charlton and Arnell, 2011), the adaptive capacity of water-related institutions (Charlton and Arnell, 2011; Engle, 2011) will depend on how effectively decision makers can gather the required information and knowledge; recognize the need for adaptation; and decide to undertake adaptation (Yohe and Tol, 2002). Adaptation, therefore, involves the exchange of knowledge and experience (Brown et al., 2013a,b; Adger et al., 2005; Lejano and Ingram, 2008; Ziervogel and Downing, 2004) through networks at various scales (Adger et al., 2005; Juhola and Westerhoff, 2011). The role of social networks to enhance the adaptive capacity of individuals (Benson et al., 2015), farmers (Aulong et al., 2012), communities (Brown et al., 2010), non-profit organisations (Steinberg, 2009) and societies (Clarvis

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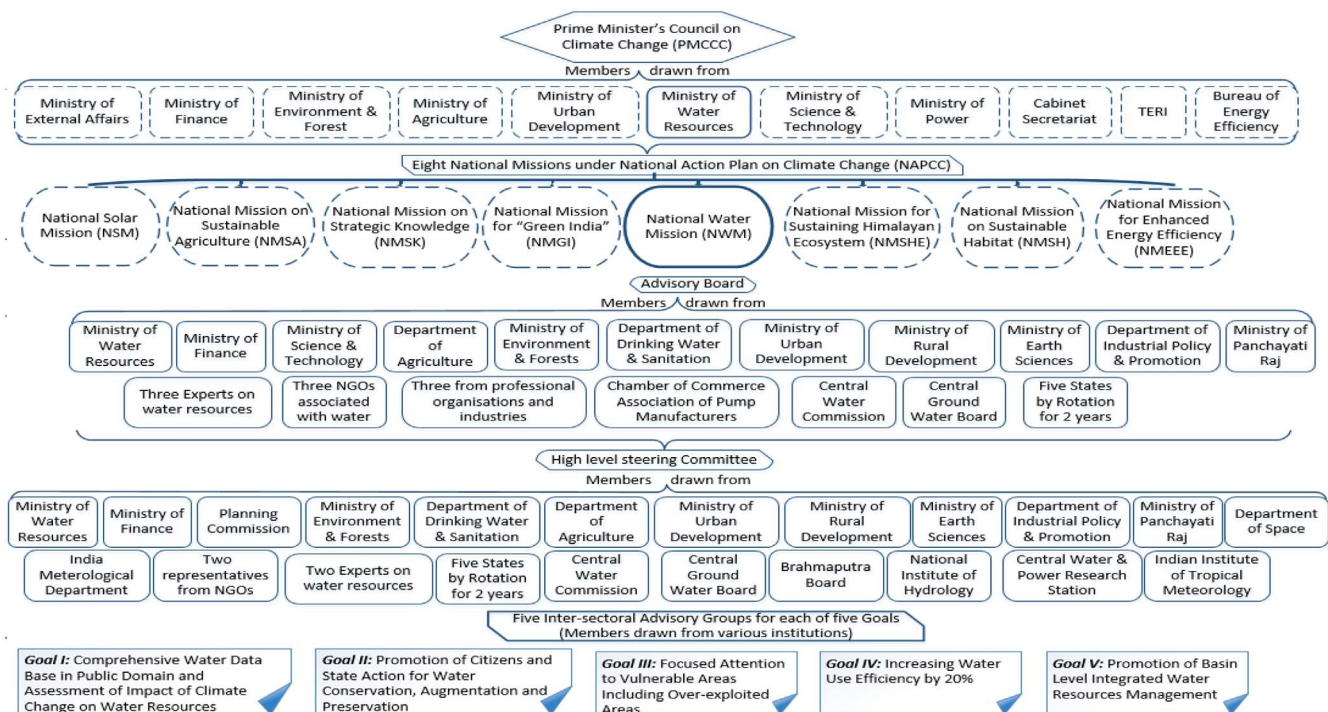


Fig. 1. Institutions involved in the National Water Mission under the National Action Plan on Climate Change in India. (Adapted from (MWR, 2011) and PMCCC, 2008).

and Allan, 2014; Davies, 2005; Dow et al., 2013; Lejano and Ingram, 2008; McAllister et al., 2014; Pasquini et al., 2015; Provan and Milward, 2001) is widely recognised. Social networks between key officials allow institutions to cross or blur formal institutional and sectoral boundaries, building 'relational capital' (Wallis and Ison, 2011) and providing "a constellation of relationships that can be activated when needed" (Lejano and Ingram, 2008; p. 251). Such inter-institutional networks are complex because institutions are made up of individuals (Pahl-Wostl, 2009) with different personalities and motivations. However, knowledge regarding networks among public institutions is very limited (Arnell, 2010). Therefore, there is a need to understand the factors and circumstances that strengthen the ties and cooperation between various institutions and sectors for information diffusion and knowledge exchange (Popp et al., 2013) that ultimately enhance adaptive capacity.

Literature on identifying characteristics and attributes that enable (Wilby and Vaughan, 2011) or hinder (Moser and Ekstrom, 2010; Sciulli, 2013) institutions to adapt to climate change is growing (Biesbroek et al., 2013). However, the circumstances under which such enabling factors are utilised, enhanced, created or shared among institutions or how adaptation barriers emerge (Azhoni et al., 2017), persist and affect the capacity of water institutions to adapt are poorly understood (Eisenack et al., 2014). Achieving the desired adaptation goals is not contingent on adaptive capacity alone, but also upon many factors such as socio-economic and cultural factors (Azhoni et al., 2017) that shape decision makers' perceptions of risks (Liu et al., 2016; Smith et al., 2014), willingness to act (Adger et al., 2009; Gifford et al., 2011; Grothmann et al., 2013) or to prioritise actions. How actors perceive what options and alternatives are under their control, and perceptions of who the key stakeholders are, is particularly pertinent for deliberating and implementing adaptation strategies (Moser and Ekstrom, 2010). Therefore, understanding the traits of the governance system regarding who has control over the processes of policy making and resources allocation will play an important role in determining the adaptation outcome (Berrang-Ford et al., 2014).

Since adaptation usually entails the involvement of key stakeholder institutions, identifying the underlying adaptation barriers to their (lack of) involvement (Azhoni et al., 2017) is pertinent. Even the best top-

down national or regional plans may not necessarily translate into successful adaptation (Preston et al., 2010), as adaptation is context specific (Eisenack et al., 2014) and contingent upon such factors as the aptitude and attitude of implementing agencies towards risks (Berkhout, 2012; Wilby and Vaughan, 2011), political and circumstantial priorities (Haddad, 2005) and the availability of resources and technology. Exposing the factors that stop, divert or delay institutions to effectively adapt are crucial in the adaptation process (Berkhout, 2012). Although adaptation research is transitioning from awareness raising to strategizing adaptation (Mimura et al., 2014), few studies demonstrate that adaptation is occurring (Moser and Boykoff, 2013). The limited reports of actual adaptation (for example, Tompkins et al., 2010) are confined to industrialised countries that afford lesser relevance to developing countries that have competing developmental and economic priorities. Therefore, in this study, while we unpack the complexities of inter-institutional relationships and their individual and joint involvement in climate change adaptation in the context of water management, we aim to identify and expound adaptation and network barriers by looking at the complexities in a large and multi-faceted context exhibited by a developing economy, India.

1.1. Context: climate change adaptation in India

Facilitating adaptation is particularly important in the Indian subcontinent, where climate change is likely to impact a billion people (Immerzeel et al., 2010) and magnify the existing water management challenges of growing demand (Bhuiyan et al., 2009; Mukherjee et al., 2010), poor performance and deteriorating infrastructure (Ananda et al., 2006; Basu and Joshi, 2000). India is a welfare state (Narain, 2000) where government institutions both frame laws and policies (Saleth, 2004), meet water demands and manage water related disasters (Ananda et al., 2006). At the Union (national) Government level, multiple ministries have responsibility within the water sphere, supported by many agencies and research institutions. This institutional complexity is evident (Fig. 1) within the current National Water Mission (NWM) (MWR, 2011) that is being implemented under the National Action Plan on Climate Change (NAPCC) (PMCCC, 2008).

This research focusses on Union Government Ministries, govern-

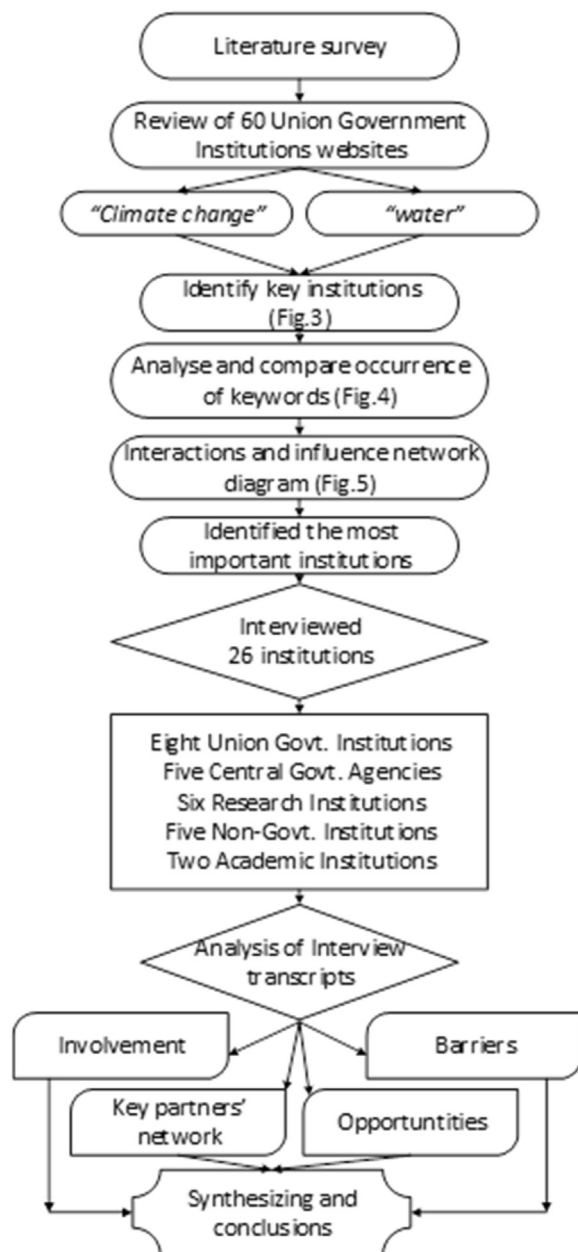


Fig. 2. Schematic of the methodological approach of the study.

ment agencies and departments, research and academic institutions and non-governmental organisations (collectively referred to as institutions) that have a stake in the water sector in India. It seeks to understand the inter-relationships between these institutions in a complex top-down bureaucratic system of water governance. We aim to understand the strengths of ties and cooperation between various institutions and sectors so as to identify barriers and bottlenecks (Biesbroek et al., 2013; Eisenack et al., 2014; Moser and Ekstrom, 2010) to information diffusion and knowledge exchange (Popp et al., 2013; Ziervogel and Downing, 2004), and thereby identify the key opportunities (McNeeley, 2012) to develop more effective networks for adaptation between different sectors and stakeholders (Hamlet, 2011).

2. Methods and material

This research uses qualitative and quantitative approaches (Fig. 2) to identify and evaluate the involvement of key national-level institutions in India in climate change adaptation for water management.

Their involvement, interests, inter-actions, and adaptation barriers were evaluated in two stages: a) quantitative internet data mining of the external-facing online presence of Union Government institutions to identify key institutions, supplemented with b) qualitative analysis of interviews with key representatives.

2.1. Analysis of online presence for external portrayal of interest and influence

National e-Governance initiatives in India and the Right to Information Act, 2005 (GoI, 2005) mandate government institutions to proactively make information publicly accessible. Consequently, most government reports, including documents related to the formulation and implementation of the National Water Mission, consultation workshops, trainings and seminars, funding and recruitment are available via the government websites. This enables the interest/involvement of Union Government institutions and the potential inter-actions/influence between them to be evaluated based on their online presence and thereby identifies the key players in the national discourse on climate change adaptation for water management.

The websites of sixty Union Government institutions (listed in Supplementary materials) were systematically searched using the Advanced Google search engine (https://www.google.co.in/advanced_search) during 13–23 May 2013 to identify those institutions with the greatest public-facing interest/activity in water and climate change on the basis of the total number of webpages and downloadable PDF and Word documents (hereafter referred to as online returns) containing the keywords “water” or “climate change”. Key institutions were identified according to whether the total number of online returns or the number per thousand indexed webpages (to avoid disadvantaging smaller institutions) exceeded a threshold value denoted by a significant discontinuity in the distribution of online returns. Selection based on threshold number, instead of a mean, median or quartile, ensured that key institutions were identified on the basis of a noticeable difference in their external portrayal of interest and influence in a sample where the numbers of online returns detected were highly variable.

Within the subset of identified key Union Government institutions, two further broad searches were carried out on their websites to identify online returns based on:

- the keywords [“adaptation” AND “climate change”]; [“adaptation” AND “climate change NOT mitigation”]; [“Mitigation” AND “climate change”] and [“mitigation” AND “climate change” NOT “adaptation”] to evaluate the relative institutional emphasis between mitigation and adaptation in their climate change discourse.
- the keywords [individual name of the other 59 institutions] AND [“climate change” AND “water”] to identify the inter-actions or potential influence between the key institutions

Results were tabulated in a matrix and network diagrams drawn, using NodeXL (Smith et al., 2010). The potential ‘strength’ of inter-institutional ties (as given by the number of online returns with “institution name” AND “climate change” AND “water”) is denoted by the width and direction of connecting arrows; and their involvement (as determined by the number of online returns for “water” AND “climate change adaptation” in their respective website) shown by the diameter of the nodes.

2.2. Stakeholder interview analysis for internal perception of interest and influence

Quantitative analysis of the institutional websites identified those key institutions whose outward-facing public image reflects an interest in climate change adaptation for water management and also the apparent strength of inter-actions between them. However, institutions do not function in a vacuum of human agency and dynamics of human

relationships, perceptions and attitudes are complex and hard to decipher by document analysis alone. Therefore, the online analysis was supplemented by in-depth interviews with representatives from these key institutions and other institutions identified as important by these interviewees.

A semi-structured interview template (available in the Supplementary material) was framed based on a literature review and refined through two pilot interviews conducted with researchers who have knowledge regarding India and climate change adaptation. Approval of the questionnaire and interview protocol was obtained from the ethics committee. The questions assessed the interviewees' a) perceptions of climate change impacts for water management [not reported here], b) actions [or inactions] triggered by such perceptions, c) aspirations for and suggestions to address the climate change impacts, d) the barriers and challenges for adaptation, and e) their key partner institutions for adapting water management to climate change. The interviewees within eight key Union Ministries identified through the online analysis were chosen based on their work portfolio (such as being in-charge of the Climate Change Cell), or by recommendation of other respondents. In addition, Union Government agencies and research institutions that work closely with these Union Ministries and other institutions identified as important by at least two respondents were included. Participants were contacted first through email using a standardized letter followed by phone calls to arrange appointments.

All twenty-six interviews were conducted in English and audio recorded, except for four where permission was not granted. The respondents were from eight Union Ministries (coded as UM), five government agencies (GA), six research institutions (RI), five non-governmental organisations (NG) and two academic institutions (AI). Respondents were coded by these acronyms along with a numerical figure to anonymise yet retain traceability. The interviews were mostly carried out with a single representative. Interviews ranged from nine to 90 min with an average of 30 min. The length of each interview depended upon the interest and knowledge of the respondent, but only two interviews were shorter than 15 min. The shorter interviews, although unable to provide detailed insights into climate change adaptation initiatives and barriers, provided an opportunity for the interviewees to identify their key partners. Since the key aim of the interview was to identify the key institutions and examine their involvement and challenges of adaptation, we believe that the small number of short interviews did not affect the results significantly.

The interpretative approach to content analysis was guided by established methods and relied on inductive insights (Saldana, 2009). The first reading and coding of the verbatim transcripts captured the terms that respondents use in their everyday work (Saldana, 2009; p. 74) and identified the main topics that correspond to the research objectives. Following common practice in grounded theory (Bryant, 2014; Creswell and Miller, 2000; Merriam, 2009; Patton, 1999), the coding process led to the inductive identification of themes and sub-themes from the data set. Increased understanding of the data set led to frequent checks and re-organization of themes and sub-themes. The reliability of the coding process was ensured by verifying the coding of the transcripts from the most recently coded to the earliest which reduces the influence of the earliest coded transcripts (Saldana, 2009). The codes were arranged systematically into themes using QSR NVivo 10 (Richards, 1999), with the keyword “query” feature used to minimise omission of key points, and to enable review of the context in which the keywords occurred. Diverging from conventional content analysis approaches (Strijbos et al., 2006; Tang et al., 2013), higher frequency of codes is not considered synonymous with importance (Fereday and Muir-Cochrane, 2006). Nevertheless, the number of respondents emphasizing a particular point (see Appendix C of the Supplementary material) was recorded, as this constitutes an indicator of identifiable (or lack thereof) involvement and barriers.

An inter-institutional network diagram was derived from a matrix of

interviewees' identified key partner institutions using NodeXL (Smith et al., 2010) and evaluated against the inter-institutional network derived from the online analysis.

3. Findings

3.1. Involvement in climate change adaptation discourse: online presence

Fifteen Union Government institutions (Fig. 3) were identified as publicly portraying the most involvement/interest in the climate change discourse, based on having either 134 or more online returns each (Group 1 - Fig. 3) or 24 or more online returns per thousand indexed webpages (Group 2 - Fig. 3) containing the keyword “climate change”. The highest number of online returns was in the Ministry of Finance (2860) followed by the Ministry of External Affairs (2260). Similarly, eighteen institutions portrayed the greatest online involvement/interest in the water discourse. Thirteen (Group 3 - Fig. 3) have 1602 or more online returns with the keyword *water* and twelve have 209 or more per thousand indexed webpages (Group 4)

Based on this analysis, 9 institutions were identified as most involved/interested in the climate change and water discourse (being present in both Group 1 and/or 2 and Group 3 and/or 4) – Ministry of Agriculture, Ministry of Environment and Forests [renamed as Ministry of Environment, Forests and Climate Change on 26th May 2014], Ministry of Science and Technology, Planning Commission [“Planning Commission” is used here as the data was collected before it was replaced by NITI Ayog (National Institution for Transforming India), declared on 15th August 2014], Ministry of Commerce and Industry, Ministry of Railways, Ministry of External Affairs, Ministry of Earth Sciences and the Ministry of New and Renewable Energy. They were augmented by 3 institutions which showed particularly high involvement/interest in the climate change discourse (being present in both Group 1 and 2 – Ministry of Development of North-Eastern Region, Ministry of Finance and Prime Minister's Office) and 3 institutions which showed high involvement/interest in the water discourse (being present in both Group 3 and 4 – Ministry of Drinking Water and Sanitation, Ministry of Urban Development and Ministry of Water Resources).

The online returns for *adaptation* and *mitigation* keywords in the websites of these fifteen Union Government institutions consistently showed that there are more online returns for *mitigation* than *adaptation*, except for the Ministry of Development of North-Eastern Region (Fig. 4). In addition, adaptation is rarely mentioned in isolation from mitigation (Fig. 4), indicating an emphasis on mitigation in the government websites. Fig. 4 shows that the institutions highly involved in water related activities, such as the Ministries of Water Resources, Drinking Water and Sanitation, and Agriculture, have less reference to climate change than other ministries. However, this partly reflects institutional size, where, for example, the Ministry of Railways (one of the largest institutions in India) has a huge number (36,300) of documents/webpages mentioning ‘water’. However, this represents only seventy-five per thousand webpages/documents, which is much less than institutions such as the Planning Commission (438 per thousand webpages/documents) and Ministry of Agriculture (400 per thousand webpages/documents).

3.2. Quantifying involvement and influence based on online presence

Fig. 5 quantifies the online portrayal of institutional involvement (as given by the diameter of the node) and inter-institutional influence (arrow direction and width). Four Union Government institutions, viz; Planning Commission, Ministry of Environment and Forests, Ministry of External Affairs and Ministry of Agriculture show the biggest online involvement or interest in climate change and water issues. In contrast, the Ministry of Water Resources (the key institution for formulating water policy and water resources management) and the Ministry of

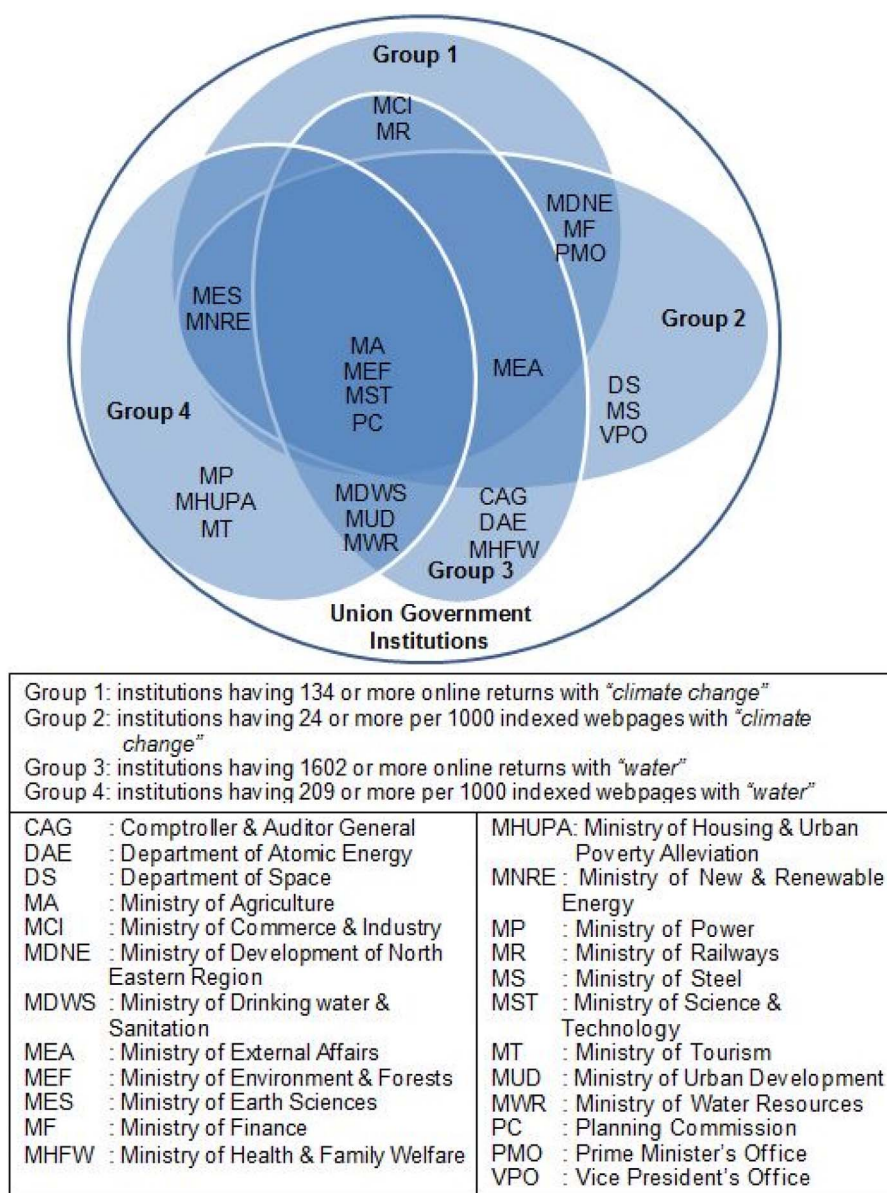


Fig. 3. Union Government level institutions with the greatest online interest in climate change and water management, based on online returns using the keywords “Climate change” and “water”.

Earth Sciences (which heads activities relating to the weather forecasts and climate studies in India) emerge as much less involved or interested.

As illustrated in Fig. 5, the Planning Commission is shown to have the greatest influence with strong ties with all the key institutions. This is unsurprising as it makes the major decisions regarding investments and infrastructure development in the country and is headed by the Prime Minister. The Ministries of Earth Sciences and Science and Technology appear to have a weak influence with all other institutions. Given the important role of irrigation in Indian agriculture that makes it the largest consumer of water, the weak influence between the Ministries of Agriculture and Water Resources is surprising, especially given that the Ministry of Water Resources is involved in the development of mega irrigation projects. The lack of apparent influence between such key institutions is suggestive of the presence of barriers to information or knowledge exchange which is explored further in the interviews with representatives in the following sections.

3.3. Key partners informed by interview respondents

The key partners identified by the representatives of each institution are shown in Fig. 6. Seventy-nine partner institutions with whom they have worked or are actively interacting with in relation to water and climate change were specified. Some respondents mentioned generic Indian Institutes of Technology (IITs), National Institutes of Technology (NITs) or Non-Governmental Organisations (NGOs) and each have been aggregated.

The Ministry of Water Resources and the Indian Institute(s) of Technology were most commonly mentioned as key partners (eight each), followed by the Ministry of Environment and Forests (seven respondents). Four institutions; TERI (The Energy and Resources Institute), National Institute of Hydrology, Ministry of Urban Development, and Ministry of Agriculture followed these with five each. The prominent importance of the Ministry of Environment and Forests and Ministry of Agriculture in Fig. 6 corroborated the online

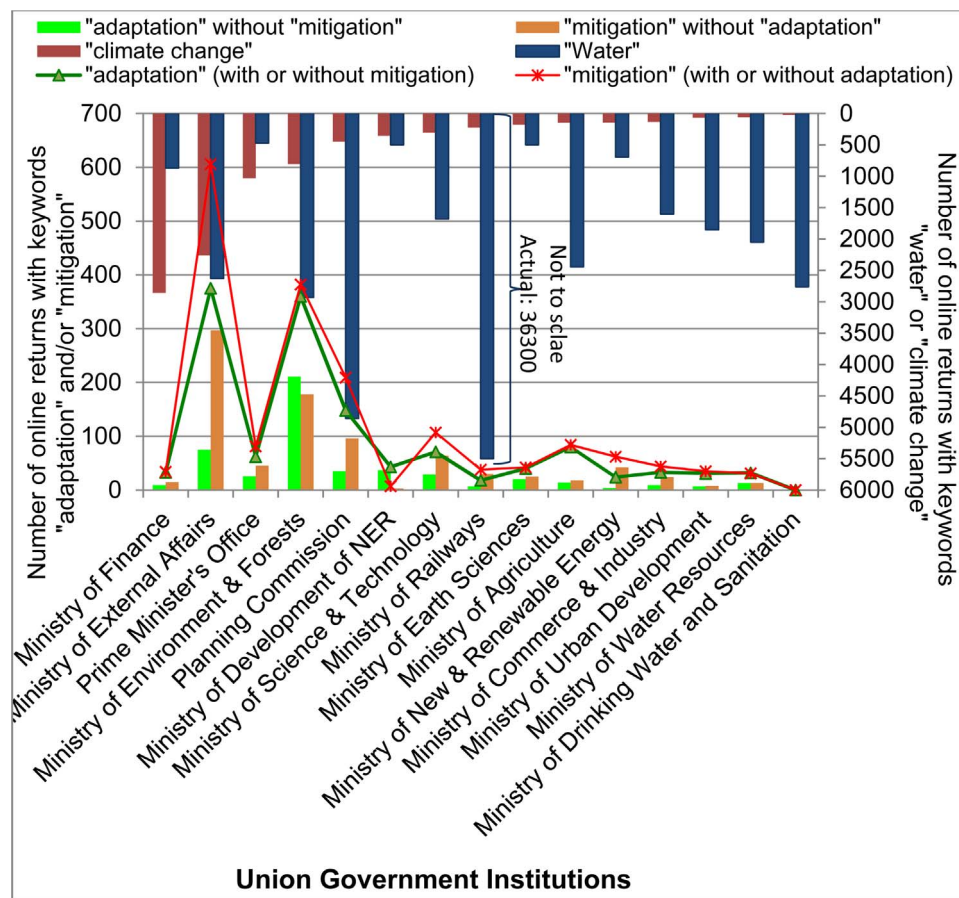


Fig. 4. Comparison of Union Government institutions' online returns with "water", "climate change", "adaptation", and "mitigation" keywords (Searched during 13–23 May 2013).

perception of significant involvement (Fig. 5). However, the interviewees' assessed the importance and influence of the Planning Commission (which plays a key role for planning infrastructural development in India), Ministry of Earth Sciences and Ministry of Science and Technology, as much lower than suggested by their online presence. In contrast, the Ministry of Water Resources and Ministry of Drinking Water and Sanitation, which portray little online interest in climate change adaptation, were commonly cited by respondents.

3.4. Findings from interviews with key representatives

The findings from the interviews are presented in three sections: (1) involvement in adaptation initiatives; (2) barriers to adaptation; and (3) creating enabling mechanisms.

3.4.1. Involvement in climate change adaptation

Interviewees' involvement in climate change adaptation activities can be categorised into four broad groups (Table 1). The most common activity is to build the adaptive capacity of water users, municipal engineers and government officials by raising awareness through seminars, workshops etc. This includes demonstrating adaptation measures at the local level by, for example, teaching local communities to plan, design and manage rainwater harvesting structures, and local reuse of water. Research to better understand regional projections of climate change, and associated impacts and vulnerability, and the collection of hydrological data to inform analysis, research and management/policy responses, were also mentioned.

NGO interviewees described their involvement in advocacy and building inter-institutional networks for information dissemination, in

contrast to the Union Government Ministries and Government Agencies. Some research interviewees also stated their involvement as brokering linkages between government agencies and departments, in addition to involvement in framing policies and guidelines for reducing water demand. Most interviewees were aware of the government's recent adaptation planning initiatives within the National Water Mission and other Missions under the NAPCC, but their own activities are largely addressing current problems of increasing water demand and extreme events rather than purposefully addressing climate change adaptation.

3.4.2. Barriers: factors stopping institutions from adapting water management to climate change

The main barriers to adapting to climate change for water management in India are summarised in Table 2. A lack of capacity, which includes knowledge of climate change and lack of financial resources, technology, and infrastructure were the most cited barrier. Many respondents identified knowledge deficits as a major barrier at various levels, due to the disconnection between researchers, policy makers, practitioners and local communities. For example: 'more than ninety percent of the research that is going on in the climate change is not going to help the adaptation for community because the most important stakeholder ... are not included in that planning' (NG14).

The lack of infrastructure as well as its deteriorating state was highlighted: 'the present systems particularly in irrigation ... is not in a good shape. Over the years systems have deteriorated – particularly the conveyance system. So a huge capital is required and that is a challenge' (GA01). 'Our paradigm has been to build certain thingsdo not manage it properly... deteriorated and then we rebuild.... we didn't have proper

institutions to manage them effectively and properly' (RI14). Deteriorating infrastructure has meant that the water institutions are occupied with addressing current deficiencies rather than future concerns.

Eleven respondents cited barriers due to bureaucratic hurdles and delays in project approvals and systemic deficiencies. Respondents expressed scepticism about the ability of existing institutional mechanisms to deliver adaptation policies and strategies being framed by the Government through the National Water Mission. Bureaucratic processes delay or render data and information (which are with government agencies) inaccessible, despite protocols to make non-restricted data accessible, hindering or delaying research and adaptation planning:

'You have to write to the concerned head of the department or the institute and then he will mark [delegate] to the concerned officer to give the relevant information. So difficulties are there and procedures are definitely not so simple' (AI25)

Ambiguities in the responsibilities between the State and the Union and of groundwater ownership were commonly cited as resulting in institutional bottlenecks. A respondent stated that 'India is highly under prepared' (NG15) to address climate change impacts for water management. He suggested that the challenges will become visible at the implementation stage: 'the proof will be in the pudding, ... when the work starts... we are going to run into ... institutional bottlenecks' such as 'the jurisdictional [ambiguities]...between the Centre and the States... because water is by definition a "state issue" [but] most of these problems cannot be tackled at the state level. There has to be a basin level approach [which requires that] more than one State has to collaborate, but the "battle between one State and another... is going to be a major challenge" (NG15). In addition to this, '[the] juridical and legal framework for groundwater... is still a grey area... even the national water policy has not properly enunciated ... States have not agreed' (NG15). In a similar manner: '... lots of debates come whether water is a State issue. ... when it comes to policy making or implementation, it gets affected because there is a lack of clarity' (UM13).

One of the main barriers to climate change adaptation is the lack of effective coordination within the 'unorganized' (RI11) water sector which was identified by respondents from government institutions, NGOs and research institutions. Many respondents from the government institutions admit that they work in silos and do not share data, which is compounded by the lack of adequate human resources that constrains effective coordination and the maintenance of active networks, even though they get 'good responses' (GA01) from other sectors and institutions. Frequent changes of personnel due to departmental transfers, particularly in the government institutions, hinder the development of long-term relationships.

Many of the identified barriers are inter-related and multi-layered. The weak institutional structure means that adaptation plans and strategies framed at the Union level fail to be adequately implemented. This is compounded by poor monitoring and ineffective follow-up of adopted strategies: 'the subsequent follow up was not up to the mark; up to the level that it should have been' (RI17). An NGO representative described an example of the gap between stated protocols and implementation:

'... every agriculture department at the block level have to record the rainfall data. ... But that is only provision. We need a mechanism for monitoring also whether those data are being recorded or not. If they are not recording what is the problem they are facing' (NG14)

The lack of a strong cohesive network among the institutions involved in water management means that:

'Water sector ... where almost eleven ministries are already looking into water from their own perspectives and they are all in their own eyes. So the problem is one institution does not speak to the other and therefore the integration is not there' (RI11)

Climate Change Cells, a unit within a government department often with additional responsibility but without additional manpower, have been established in many of the State and Union Government Ministries and are supposed to coordinate climate change activities. However, a

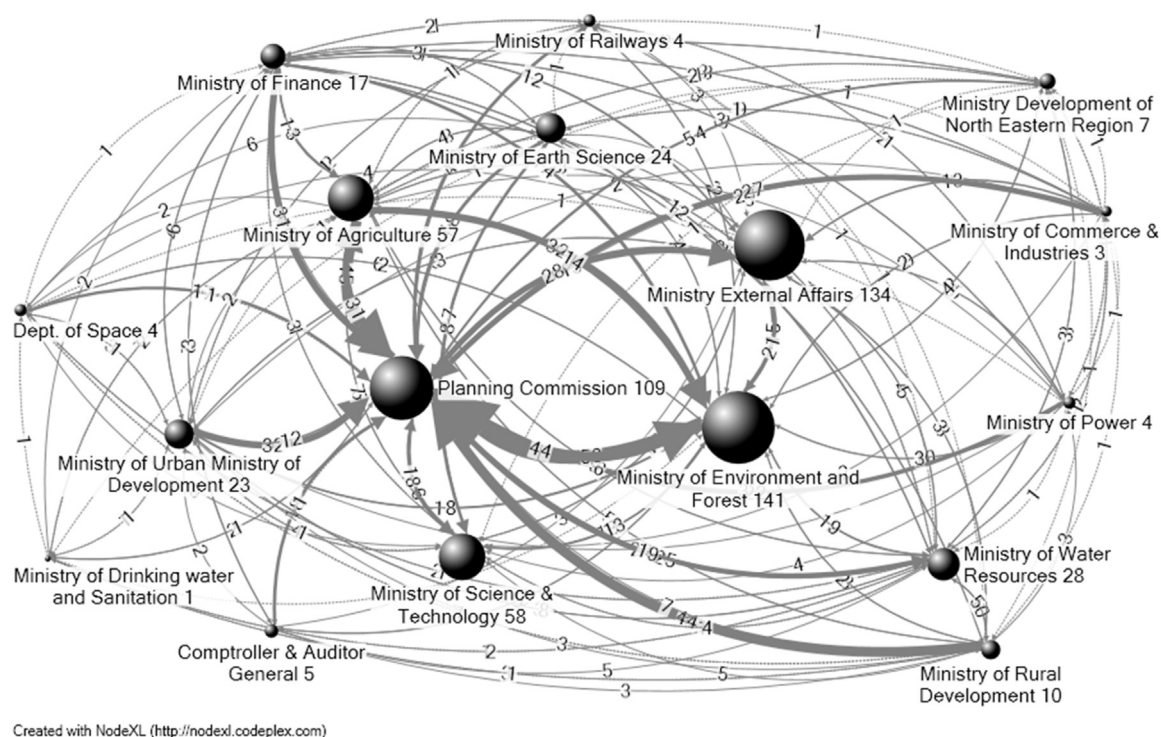


Fig. 5. Web-based networks of involvement/interest (size of nodes and 'n' adjacent to institution name) and influence (width of arrows) in climate change adaptation for water management for six key institutions.



respondent, reflecting on the experience of working with State Government departments, noted that the Climate Change Cells are not fully integrated with the other departments and end up being non-functional:

‘When we talk about the climate change, a lot of the States in India have Climate Change Cells but what is happening right now is that the schemes get directly implemented through different departments. ... The Climate Change Cell is just becoming standalone over there’ (NG21)

3.4.3. Creating enabling mechanisms: aspirations and suggestions

Table 3 presents key strategies or opportunities suggested to overcome the identified adaptation barriers. Single respondent views were regarded as equally valid as those suggested by multiple respondents. The suggestions of many of the respondents flow from what they are already doing. For example, those who stress the need to involve local communities and improve networking and coordination among key stakeholders are those already involved in building networks for policy advocacy:

‘There are other stakeholders, you may call it beneficiaries, they have to be roped into the plan and in water sector it is very important for the success and sustainability of an intervention. ... Therefore like we do in our projects, the stakeholder participation has to be right from the planning stage wherein you not only listen and you not only look into the science and the impacts which is scientifically driven or scientifically understood and derived’ (RI11)

The need for bottom-up engagement of water user communities as key stakeholders within adaptation planning is stressed by NGOs: *‘what we say is basically the need for paradigm change. The way the water is handled today ... is more institutional. There is no role of community, role of users/beneficiaries. How we can conserve water...’* (NG09). In contrast, research institutions tended to suggest restructuring of water governance institutions with an emphasis on the basin level approach or integrated catchment framework, while the Union Ministries emphasise top-down: *‘when the programs are made at the Central level at the highest level, we are using a top-down approach. So we should do the convergence also from the top-down’* (UM16).

Since *‘climate change is bottom up as well top down’* (NG21), the need for more effective vertical coordination is stressed. All respondents acknowledged the need to strengthen inter-organisational networks to enhance adaptive capacity. Inter-institutional networks, such as the Indian Network on Climate Change Assessment (MEF, 2010; Sharma

and Chauhan, 2011), are being promoted in India for knowledge sharing and collaborative research and advocacy. However, it is the NGO representatives who are more actively involved in network building initiatives, such as CAN-SA (Climate Action Network: South Asia) and VANI (Voluntary Action Network India).

Most respondents stressed the importance of the State Governments’ role in climate change adaptation for water management and the need for State governments to play a greater role in order to change the habits and culture of water users to achieve efficient utilisation of water. Whilst the Union level institutions analyse the system from the national perspective, they expect the actual implementation to be carried out by the State governments. The main interaction is through the allocation of financial resources from Union Government to State government institutions so that the State governments can *‘establish the demonstration programs of best practices so that people will be able to replicate those kinds of practices’* (UM2).

Government agencies desired the adoption of more efficient technologies for hydrological monitoring and water use and improved water infrastructure including through increased storage capacity. The need to develop guidelines and standards for improving water use efficiency and incorporating climate change factors into flood estimation was suggested by NGO representatives, government agency practitioners and research scientists. Dissemination of information, including free access to restricted hydrological data, was desired by NGOs and research institutions. The soft skills, such as the capacity to understand risks and take appropriate contextual measures, for enabling adaptation were also emphasised: *‘But more than that ... [storage structures]... the software part is really important ...we have to improve the... software part of the management’* (RI04). In a similar manner another respondent emphasised: *‘at the moment software is more important than the hardware’* (RI11).

4. Discussion

Water institutions are generally analysed from two perspectives; from internal institutional design principles and/or the institutional environment such as the legal laws in which the institution operates (Ananda et al., 2006; Blomquist et al., 2004; Gandhi and Namboodiri, 2009). This research goes beyond both of these and includes an analysis of the inter-institutional inter-actions necessary to understand the barriers and the opportunities for creating enabling mechanisms (Biesbroek et al., 2013). Moreover, combining quantitative assessment of institutions’ outward facing online presence with in-depth qualitative assessment of the views of key institutional respondents enabled the

Table 1

Involvement in climate change adaptation. ‘N’ in first column indicates the number of respondents whose transcripts contain the respective code.

Involvement	Illustrative example quotes
Building capacity [N = 10]	<p><i>‘We are regularly conducting training’</i> (GA12)</p> <p><i>‘We organised a workshop ...[with] state government’</i> (GA01)</p> <p><i>‘We train them how to plan, design and implement best management’</i> (NG09)</p> <p><i>‘We are involved to disseminate knowledge on the rain water harvesting’</i> (RI07)</p>
Vulnerability and impact assessments [N = 8]	<p><i>‘...lots of works in understanding the glacial hydrology and how due to the climate it is being affected’</i> (AI06)</p> <p><i>‘We have now entered into climate modelling’</i> (RI11)</p> <p><i>‘We are more interested in research and development of how the water cycle is changing’</i> (UM18)</p>
Building networks and advocacy [N = 8]	<p><i>‘We are creating a network of NGOs to disseminate information on climate change issues’</i> (NG14)</p> <p><i>‘We are targeting ...establishing knowledge management platform for the Ministry of Agriculture to disseminate and collect ...information for ...adaptation’</i> (NG14)</p> <p><i>‘We network with a fairly wide network of group of NGOs and Civil Society organisations...fifty or sixty organisations’</i> (NG15)</p> <p><i>‘I was in a case ... to bring in all the departments together ... because they then will understand what are the linkages, cross-linkages of issues amongst them and therefore what is the need for them to actually work in a very coordinated manner’</i> (RI11)</p>
Policy interventions and guidelines [N = 7]	<p><i>‘...involved in the draft for National Action Plan on Climate Change’</i> (RI11)</p> <p><i>‘We provide inputs to the National Water Mission’</i> (UM18)</p> <p><i>‘We have revised the National Water Policy ...and now working on the implementation ... of the Water Mission’</i> (GA01)</p> <p><i>‘One of the adaptation strategies we produced on water use [efficiency]... We do not have an Indian standard before. I am one of the panel members on ...water efficiency’</i> (NG09)</p>

Table 2

Main barriers to adaptation. ‘N’ indicates the number of respondents whose transcripts contain the respective code.

Barriers	Illustrative example quotes
Lack of knowledge capacity, financial and human resources, technology, and infrastructure N = 12	<i>‘not possible with the limited infrastructure’</i> (GA12) <i>‘government agencies lack capacity’</i> (NG15) <i>‘detailed study is not there under the climate change scenario’</i> (RI07) <i>‘The biggest challenge with climate change as of now is uncertainty’</i> (RI11) <i>‘we do not have barefoot hydrologists’</i> (A106)
Bureaucratic and systemic deficiencies N = 11	<i>‘Government systems are mammoth systems and [laughs]... it takes time for things to be materialised by the government’</i> (GA01) <i>‘bureaucratic processes and excesses becomes a little difficult’</i> (NG21) <i>‘the government agencies...providing that link are quite weak ...there is no flow of the information from the upstream to downstream’</i> (RI14) <i>‘the mission mode implementation requires a different arrangement...total freedom to work’</i> (UM13)
Poor coordination and awareness N = 8	<i>‘It is an institutional problem of how to bring multiple agencies together’</i> (NG15) <i>‘the problem is one institution does not speak to the other and therefore the integration is not there’</i> (RI11) <i>‘the systems of collaboration is still very weak’</i> (RI14) <i>‘Many organisations, ministries ...states are involved in the water resources management... So to manage all the departments ... is the main challenge’</i> (UM18)
Inadequate policies and conflicts of interests N = 7	<i>‘India is actually highly under prepared... in terms of adaptation... to build climate resilient policies’</i> (NG15) <i>‘totally unorganized’</i> (RI11) <i>‘when it comes to policy making or implementation... there is a lack of clarity [between Centre and State]’</i> (UM13)
Inaccessibility to information and data N = 6	<i>‘...you can’t find the temperature and rainfall data at the block level. There is no data available there. How we can make a plan?’</i> (NG14) <i>‘Unfortunately the classified region covers nearly two-third of our water resources’</i> (RI17)
Lack of involvement of user communities N = 5	<i>‘There is no role of community, ...users [and]... beneficiaries. How we can conserve ...[and] manage water [without their involvement]?’</i> (NG09)
Other challenges due to growing demands N = 4	<i>‘the challenge is to first provide them with basic amenities then talk about conserving or adapting’</i> (NG09)

identification of key institutions and their (lack of) involvement from both perspectives, in addition to understanding the practitioners’ perspectives of practical barriers.

The keyword analysis of the online documents of the Union Government institutions in Fig. 3 is revealing. Although all Union Government institutions are similar in certain aspects; each of them headed by a Minister, for example, their responsibilities and the nature of public engagement varies. Depending on their specific mandates and priorities, the degree of involvement in climate change adaptation discourse is expected to vary. However, institutions such as the ministries of Water Resources, Drinking Water Supply and Sanitation, Urban Development, and Agriculture, which would be expected to be sensitive to the impacts of climate change and therefore visible in the climate change discourse, make infrequent reference to climate change in their online documents compared to institutions such as ministries of Finance and External Affairs (Fig. 4). This indicates the need for a greater involvement by the climate sensitive institutions in the discourse, even though the involvement of the ministries of External Affairs and Finance is unsurprising given the global nature of climate change, India’s many transboundary rivers and the availability of financial resources being an important determinant of adaptive capacity. However, the lesser visibility of climate sensitive institutions such as Ministries of Water Resources, Earth Sciences, Agriculture raises concern. Whilst the less visible references to “climate change adaptation” in their online documents may arise from many climate change impacts being indirect, such that adaptation actions are not named, if the Government of India claims to have a commitment for making its activities more transparent and making its information more accessible to the public (GoI, 2005; Prasai and Surie, 2015), increasing the online visibility by these water sensitive institutions is desirable.

The online documents analysis indicate a contrasting view point to Thaker and Leiserowitz (2014) who reported a shift in the climate change discourse in India towards recognising the co-benefits of aligning its development and climate change objectives. The (online) documents indicating a greater reference to mitigation rather than adaptation could be due to the more recent shift in global emphasis to

adaptation (Handley et al., 2006; Klein et al., 2005); but it also reflects a preference for top-down mitigation activities in contrast to adaptation as a bottom-up activity.

Climate change will be particularly experienced through a changed water cycle (Goodess, 2012; Kumar et al., 2011; Mathison et al., 2012), so an understanding of their inter-relationship would be expected in government documents. The inverse correlation between the online returns for “water” and “climate change” (Fig. 4) indicates a potential disjoint in the climate impacts and vulnerability discourse at the government level, notwithstanding the differences in institutional size, mandates and responsibilities. Union Government institutions such as the Ministries of Drinking Water Supply and Sanitation, Power, Water Resources, and Urban Development portray greater interest in water than climate change. This suggests that the understanding of climate change impacts on water governance (Balasubramanian and Birundha, 2012; Charlton and Arnell, 2011; Eriksson et al., 2009; Thampi and Raneesh, 2012) is being largely ignored, leading to an apparent lack of high-level concern for adaptation (Mastrandrea et al., 2010; Moors et al., 2011).

It would be hoped that the quantitative online and qualitative interview analyses produce harmonised and consistent outward and inward perspectives. However, the online visibility of national-level institutional interactions contrasts with the perspectives of many institutional representatives. For example, the Planning Commission has a very strong online presence due to its influential role in financial resource allocation for infrastructure development in India, but officials from the various implementing institutions do not identify it as a key partner for activities related to adapting water management to climate change. In contrast, the Ministry of Water Resources has a very limited online presence that is suggestive of a weak leadership role within the climate change adaptation discourse. Although they coordinate advisory committees drawn from different Union and State Government institutions (Fig. 1) supporting the National Water Mission under NAPCC, respondents are sceptical of the ability of existing institutional mechanisms to deliver associated adaptation policies and strategies. This is suggestive of a leadership gap between the aspirational ideals

Table 3
Strategies for removing adaptation barriers suggested by interviewees.

Suggested strategies	Representative quotes
Behavioural, cultural or attitudinal change	<ul style="list-style-type: none"> • ‘address water as a resource and community’s role in water management at the forefront’ (NG09) • ‘improve the understanding of the people who are supposed to manage water’ (NG09) • ‘you have to work with the community’ (NG14)
Institutional and structural change	<ul style="list-style-type: none"> • ‘There has to be a basin level approach.’ (NG15) • ‘integrated framework of water management’ (RI11) • ‘Gradually it should be part of the process where their capacity building awareness program has to be regularly sunk into their activities.’ (RI11) • ‘barefoot hydrologists ... who can really work in the field ... collecting data and information’ (AI06) • ‘each state [should] see what is the kind of scenarios in their own states and try and link with other agencies’ (RI11) • ‘integrate our state priorities and programs in line with the scientific outputs’ (RI11) • ‘guidelines definitely have to be there’ (RI11) • ‘the drive has to be from the top’ (RI11)
Operational and technological change	<ul style="list-style-type: none"> • ‘use of latest technologies and tools’ (GA01) • ‘need for artificial recharge’ (GA24) • ‘besides increasing ... efficiency.... increase ... water storing capacity’ (GA01) • ‘Rainwater harvesting is definitely one important thing’ (NG21) • ‘we also need a lot of innovative and new technologies or low-cost technologies for irrigation’ (NG21) • ‘efficient tools and technologies [for] water conservation’ (RI11) • ‘capacity building has to be more intensive and more frequent’ (RI17)
Development and dissemination of knowledge	<ul style="list-style-type: none"> • ‘incorporate climate change aspects in probable maximum flood analysis’ (GA01) • ‘Guidelines ... for water use efficiency’ (UM20) • ‘everything [should be] on the website’ (RI07) • ‘capacity building has to be more intensive and more frequent’ (RI17)

within the National Water Mission and the realities of climate change adaptation.

The interviewees in this research are key officials in important water management-related institutions in India and their understanding of potential climate change impacts on water management are consistent with government documents (such as, MEF, 2010, 2009; MST, 2010; MWR, 2011). Beliefs and perceptions of risk are an important first step towards adaptation (Adger et al., 2009; Richards et al., 2013) as they have significant impact on decision makers (Halady and Rao, 2010), potentially influencing policies and actions for creating the physical and institutional environment for adaptation (Hinkel, 2007) and shaping how institutions adapt to climate change (Berkhout, 2012; Eisenack and Stecker, 2012). Respondents from institutions operating at the national Government level believe their role is to enhance the adaptive capacity of implementing agencies at the State or local level through formulating and evolving policies that facilitate the translation of capacity into action (Eisenack and Stecker, 2012), and creating networks of institutions to share knowledge and information. Consequently, respondents predominantly stated their adaptation intent or objectives, rather than actual adaptation actions; demonstrating that perception of risk at the national (Union) level does not necessarily lead to adaptation (Lesnikowski et al., 2013).

Although cases of purposeful adaptation reported by interviewees are limited, a broad range of enabling activities are being initiated to overcome barriers and develop the cross-sectoral cooperation needed to facilitate adaptation (Hinkel, 2007) including capacity building, making resources available and/or fostering a conducive environment for adaptation. Climate change is a complex, multifaceted and on-going process (Adger et al., 2005; Brown et al., 2013a,b; Moser and Boykoff, 2013) that requires actions by individuals, communities, governments and international agencies across multiple sectors (Berkhout, 2012; Huntjens et al., 2012; Simonet, 2010), which is being recognised by the respondents from key national level institutions.

There is clear recognition of the importance of raising awareness (Tang et al., 2009), building capacity (Engle, 2013; Keys et al., 2013), information and resources sharing through effective networks. The success, or otherwise, of these activities by Union level institutions will become visible at the local level where enhanced adaptive capacity is needed to deliver actions that are local and contextual (Halder et al., 2012). Significantly, the lack of resources, although mentioned by

many respondents, is neither the most important nor the most commonly cited barrier in this study. The core issue is the lack of institutional mechanisms for facilitating the translation of existing resources into adaptation. Many of the barriers identified here are not specific to climate change alone. The study shows that barriers such as lengthy bureaucratic protocols for decision making and resources allocation (Samra, 2004), deficient monitoring and implementation of policies, poor coordination between different government departments and ministries, and inaccessibility and unavailability of data and information are part of the wider governance issues. Overcoming these barriers is, therefore, necessary to ensure that adaptation is not constrained by the uncertainty of the magnitude of future impacts (Adger et al., 2009) but also for effective governance of water and utilisation of resources. Although barriers such as bureaucratic delays, inaccessibility of available data, unclear or overlapping responsibilities and lack of post-implementation monitoring are not unique to India (Ballard et al., 2013; Biesbroek et al., 2014; Gifford et al., 2011; Hamlet 2011; Sietz et al., 2011; Sciulli, 2013), they arise in India as a consequence of specific cultural and behavioural attitudes and institutional bottlenecks in addition to resource limitations (Azhoni et al., 2017). Barriers arising due to conflicts over sharing of resources (financial and natural) between institutions operating in different sectors and regions in India are further elaborated by Azhoni et al. (2017).

As a consequence, the barriers identified are largely manmade and malleable (Moser and Ekstrom, 2010) and hence can be overcome with sufficient political will through continual improved institutional design (Huntjens et al., 2012) that incorporates effective planning, implementation and monitoring, polycentric governance that enables active and equitable involvement of stakeholders and proper allocation and utilisation of resources. Since overcoming barriers requires time (Eisenack et al., 2014) and is difficult to confirm its success (Berrang-Ford et al., 2011), it requires continuous evaluation and iteration. Although many respondents, particularly NGOs, insist that local communities and users should be included as important stakeholders from the inception of adaptation planning, they also recognize the crucial role of government institutions through the dominant top-down process in the Indian water sector (Berkhout 2012; Butler et al., 2015). The government institutions, therefore, require visionary leadership (Wilby and Vaughan, 2011) to champion the implementation of adaptation

strategies, as the aspirational goals of the National Water Mission will not be delivered unless the vertical and horizontal inter-institutional networks are strengthened to operationalize the intended adaptation.

Creating the enabling environment needed to deliver climate change adaptation in the water sector in India will require behavioural and attitudinal change, in addition to institutional and structural changes and the availability of information, guidelines and resources (Azhoni et al., 2017). Achieving these changes should enable adaptation to be recognised as an opportunity for creative solutions to support continued sustainable development of India and not as an alternative to mitigation (Mastrandrea et al., 2010; Simonet and Fatorić, 2015).

5. Conclusion

This paper broadens the understanding of complex, multi-layered inter-relationships between institutions involved in climate change adaptation, depicted by India, through combining the quantitative online data-mining analysis of social networks with qualitative evaluation of multi-stakeholder involvement gained through in-depth interviews with representatives from key institutions. This novel analytical approach provides new understanding of the inter-institutional dynamics between the key institutions involved in climate change adaptation and a novel opportunity to understand the weak linkages between specific key institutions. Although the systematic online document evaluation of who is involved, interested, and with whom in climate change adaptation may provide a partial projection of how key institutions are involved in climate change adaptation, this approach is particularly relevant in an information technology era in which institutional websites, rather than buildings, provide the public image that people 'visit' and draw conclusions as to the institution's mandate, involvement and interest.

The limited emphasis given to adaptation in the Indian Union-level Government institutions' online presence reflects their preference for top-down mitigation activities in contradiction with the National Water Mission. The online document analysis also identifies a disjoint in the climate change and water discourse at the government level as a consequence of the complex vertical institutional framework and the Union-State tension over water. Union Government institutions believe their role is to enhance the adaptive capacity of implementing agencies at the State or local level through formulating policies that facilitate the translation of capacity into action and creating networks to share knowledge and information. The awareness and acknowledgement of interviewees of likely climate change impacts on water management and their desire to engage constructively represent valuable opportunities for creating the enabling mechanisms for adaptation and for improving water management in India. However, barriers such as bureaucratic delays, data inaccessibility, unclear responsibilities and lack of post-implementation monitoring arise in India as a consequence of unique cultural and behavioural attitudes and institutional bottlenecks in addition to resource limitations. Improved vertical and horizontal understanding of inter-institutional networks will support the vital role of networks for creating the necessary enabling conditions for adaptation and also for effective governance of water and utilisation of resources.

This study suggests that, in a developing country context, climate change is rarely the sole motivation for adapting water to climate change so that the perceived opportunities that climate change may bring lie in enabling policy-makers to allocate additional resources for water infrastructure development. The findings of this study suggest that adaptation strategies in developing countries, such as India, need to be aligned with delivering co-benefits from developmental projects. However, developing countries, such as India, that have a complex multi-layered system of water governance need to address the institutional and systemic challenges that hinder the smooth coordination and accessibility to data and information and the competing priorities of infrastructural and technological developmental priorities.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.gloenvcha.2017.04.005>.

References

- Adger, W.N., Arnell, N.W., Tompkins, E.L., 2005. Successful adaptation to climate change across scales. *Glob. Environ. Change* 15, 77–86. <http://dx.doi.org/10.1016/j.gloenvcha.2004.12.005>.
- Adger, W.N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D.R., Naess, L.O., Wolf, J., Wreford, A., 2009. Are there social limits to adaptation to climate change? *Clim. Change* 93, 335–354. <http://dx.doi.org/10.1007/s10584-008-9520-z>.
- Ananda, J., Crase, L., Pagan, P.G., 2006. A preliminary assessment of water institutions in India: an institutional design perspective. *Rev. Policy Res.* 23, 927–953. <http://dx.doi.org/10.1111/j.1541-1338.2006.00239.x>.
- Arnell, N.W., Delaney, E.K., 2006. Adapting to climate change: public water supply in England and Wales. *Clim. Change* 78, 227–255. <http://dx.doi.org/10.1007/s10584-006-9067-9>.
- Arnell, N.W., 2010. Adapting to climate change: an evolving research programme. *Clim. Change* 100, 107–111. <http://dx.doi.org/10.1007/s10584-010-9839-0>.
- Aulong, S., Chaudhuri, B., Farnier, L., Galab, S., Guerrin, J., Himanshu, H., Reddy, Prudhvikar, 2012. Are South Indian farmers adaptable to global change? A case in an Andhra Pradesh catchment basin. *Reg. Environ. Change* 12, 423–436. <http://dx.doi.org/10.1007/s10113-011-0258-1>.
- Azhoni, A., Holman, I.P., Jude, S., 2017. Contextual and interdependent causes of climate change adaptation barriers: insights from water management institutions in Himachal Pradesh, India. *Sci. Total Environ.* 576, 817–828. <http://dx.doi.org/10.1016/j.scitotenv.2016.10.151>.
- Balasubramanian, M., Birundha, V.D., 2012. Climate change and its impact on India. *IUP J. Environ. Sci.* 31–46.
- Ballard, D., Bond, C., Pyatt, N., Lonsdale, K., Whitman, G.P., Dessai, S., Evans, M., Tweed, J.H., 2013. PREPARE - Barriers and Enablers to Organisational and Sectoral Adaptive Capacity - Qualitative Study, Part of the PREPARE Programme of Research on Preparedness, Adaptation and Risk, Final Report for Project ERG1211 by Ricardo-AEA for Defra. Report Reference Ricardo-AEA/R/ED58163/PREPARE R1a/Issue 1.0. .
- Basu, P.K., Joshi, S., 2000. Study for the efficient planning, control and management of water resources development projects in India. *Int. J. Water Resour. Dev.* 16, 563–570. <http://dx.doi.org/10.1080/07900620020003100>.
- Benson, D., Lorenzoni, I., Cook, H., 2015. Evaluating social learning in England flood risk management: an individual-community interaction perspective. *Environ. Sci. Policy* 55, 326–334. <http://dx.doi.org/10.1016/j.envsci.2015.05.013>.
- Berkhout, F., 2012. Adaptation to climate change by organizations. *Wiley Interdiscip. Rev. Clim. Change* 3, 91–106. <http://dx.doi.org/10.1002/wcc.154>.
- Berman, R., Quinn, C., Paavola, J., 2012. The role of institutions in the transformation of coping capacity to sustainable adaptive capacity. *Environ. Dev.* 2, 86–100. <http://dx.doi.org/10.1016/j.envdev.2012.03.017>.
- Berrang-Ford, L., Ford, J.D., Paterson, J., 2011. Are we adapting to climate change? *Glob. Environ. Change* 21, 25–33. <http://dx.doi.org/10.1016/j.gloenvcha.2010.09.012>.
- Berrang-Ford, L., Ford, J.D., Lesnikowski, A., Poutiainen, C., Barrera, M., Heymann, S.J., 2014. What drives national adaptation? A global assessment. *Clim. Change* 124, 441–450. <http://dx.doi.org/10.1007/s10584-014-1078-3>.
- Bhuiyan, C., Flügel, W.A., Singh, R.P., 2009. Erratic monsoon, growing water demand, and declining water table. *J. Spat. Hydrol.* 9, 1–19.
- Biesbroek, G.R., Klostermann, J.E.M., Termeer, C.J.A.M., Kabat, P., 2013. On the nature of barriers to climate change adaptation. *Reg. Environ. Change* 13, 1119–1129.
- Biesbroek, G.R., Termeer, C.J.A.M., Klostermann, J.E.M., Kabat, P., 2014. Rethinking barriers to adaptation: mechanism-based explanation of impasses in the governance of an innovative adaptation measure. *Glob. Environ. Change* 26, 108–118. <http://dx.doi.org/10.1016/j.gloenvcha.2014.04.004>.
- Blomquist, W., Heikkilä, T., Schlager, E., 2004. Building the agenda for institutional research on water resources management. *JAWRA J. Am. Water Resour. Assoc.* 40, 925–936. <http://dx.doi.org/10.1111/j.1752-1688.2004.tb01056.x>.
- Bohensky, E., Stone-Jovicich, S., Larson, S., Marshall, N., 2010. Adaptive capacity in theory and reality: implications for governance in the great barrier reef region. In: Armitage, D., Plummer, R. (Eds.), *Adaptive Capacity and Environmental*

- Governance. Springer, pp. 23–41. <http://dx.doi.org/10.1007/978-3-642-12194-4>.
- Brown, H.C.P., Nkem, J.N., Sonwa, D.J., Bele, Y., 2010. Institutional adaptive capacity and climate change response in the Congo Basin forests of Cameroon. *Mitig. Adapt. Strateg. Glob. Change* 15, 263–282. <http://dx.doi.org/10.1007/s11027-010-9216-3>.
- Brown, H.C.P., Smit, B., Somorin, O.A., Sonwa, D.J., Ngana, F., 2013a. Institutional perceptions, adaptive capacity and climate change response in a post-conflict country: a case study from Central African Republic. *Clim. Dev.* 5, 206–216. <http://dx.doi.org/10.1080/17565529.2013.812954>.
- Brown, R.R., Farrelly, M.A., Loorbach, D.A., 2013b. Actors working the institutions in sustainability transitions: the case of Melbourne's stormwater management. *Glob. Environ. Change* 23, 701–718. <http://dx.doi.org/10.1016/j.gloenvcha.2013.02.013>.
- Bryant, A., 2014. The grounded theory method. In: Leavy, P. (Ed.), *The Oxford Handbook of Qualitative Research*. Oxford University Press, Oxford, pp. 116–136.
- Butler, J.R.A., Wise, R.M., Skewes, T.D., Bohensky, E.L., Peterson, N., Suadnya, W., Yanuartati, Y., Handayani, T., Habibi, P., Puspadi, K., Bou, N., Vaghelo, D., Rochester, W., 2015. Integrating top-down and bottom-up adaptation planning to build adaptive capacity: a structured learning approach. *Coast. Manag.* 43, 346–364. <http://dx.doi.org/10.1080/08920753.2015.1046802>.
- Charlton, M.B., Arnell, N.W., 2011. Adapting to climate change impacts on water resources in England-An assessment of draft Water Resources Management Plans. *Glob. Environ. Change* 21, 238–248. <http://dx.doi.org/10.1016/j.gloenvcha.2010.07.012>.
- Chou, C., Chiang, J.C.H., Lan, C.-W., Chung, C.-H., Liao, Y.-C., Lee, C.-J., 2013. Increase in the range between wet and dry season precipitation. *Nat. Geosci.* 6, 263–267. <http://dx.doi.org/10.1038/ngeo1744>.
- Clarvis, M.H., Allan, A., 2014. Adaptive capacity in a Chilean context: a questionable model for Latin America. *Environ. Sci. Policy* 43, 78–90. <http://dx.doi.org/10.1016/j.envsci.2013.10.014>.
- Cook, J., Freeman, S., Levine, E., Hill, M., 2010. *Shifting Course: Climate Change for Water Management Institutions*. World Wildlife Fund (WWF).
- Creswell, J., Miller, D., 2000. Determining validity in qualitative inquiry. *Theory Pract.* 39, 124–130. <http://dx.doi.org/10.1207/s15430421tp3903>.
- Davies, A.R., 2005. Local action for climate change: transnational networks and the Irish experience. *Local Environ.* 10, 21–40. <http://dx.doi.org/10.1080/1354983042000309298>.
- Dow, K., Haywood, B.K., Kettle, N.P., Lackstrom, K., 2013. The role of ad hoc networks in supporting climate change adaptation: a case study from the Southeastern United States. *Reg. Environ. Change* 13, 1235–1244. <http://dx.doi.org/10.1007/s10113-013-0440-8>.
- Eisenack, K., Stecker, R., 2012. A framework for analyzing climate change adaptations as actions. *Mitig. Adapt. Strateg. Glob. Change* 17, 243–260. <http://dx.doi.org/10.1007/s11027-011-9323-9>.
- Eisenack, K., Moser, S.C., Hoffmann, E., Klein, R.J.T., Oberlack, C., Pechan, A., Rotter, M., Termeer, C.J.A.M., 2014. Explaining and overcoming barriers to climate change adaptation. *Nat. Clim. Change* 4, 867–872. <http://dx.doi.org/10.1038/nclimate2350>.
- Engle, N.L., 2011. Adaptive capacity and its assessment. *Glob. Environ. Change* 21, 647–656. <http://dx.doi.org/10.1016/j.gloenvcha.2011.01.019>.
- Engle, N.L., 2013. The role of drought preparedness in building and mobilizing adaptive capacity in states and their community water systems. *Clim. Change* 118, 291–306. <http://dx.doi.org/10.1007/s10584-012-0657-4>.
- Eriksson, M., Jianchi, X., Shrestha, A., Vaidya, R.A., Nepal, S., Sandstrom, K., 2009. *The Changing Himalayas – Impact of Climate Change on Water Resources and Livelihoods in the Greater Himalayas, Perspectives on Water and Climate Change Adaptation*.
- Fereday, J., Muir-Cochrane, E., 2006. Demonstrating rigor using thematic analysis: a hybrid approach of inductive and deductive coding and theme development. *Int. J. Qual. Methods* 5, 80–92. <http://dx.doi.org/10.1063/1.2011295>.
- Gandhi, V., Nambodiri, N., 2009. Water resource development and institutions in India: overview and profile. In: Crase, L., Gandhi, V.P. (Eds.), *Reforming Institutions in Water Resource Management: Policy and Performance for Sustainable Development*. Routledge, London, pp. 146–165.
- Gifford, R., Kormos, C., McIntyre, A., 2011. Behavioral dimensions of climate change: drivers, responses, barriers, and interventions. *Wiley Interdiscip. Rev. Clim. Change* 2, 801–827. <http://dx.doi.org/10.1002/wcc.143>.
- Gol, 2005. Right to Information Act (India), Parliamentary Act. <http://www.righttoinformation.gov.in/rti-act.pdf>, India.
- Goodess, C.M., 2012. How is the frequency, location and severity of extreme events likely to change up to 2060? *Environ. Sci. Policy* 1–11. <http://dx.doi.org/10.1016/j.envsci.2012.04.001>.
- Grothmann, T., Grecksch, K., Wings, M., Siebenhüner, B., 2013. Assessing institutional capacities to adapt to climate change – integrating psychological dimensions in the Adaptive Capacity Wheel. *Nat. Hazards Earth Syst. Sci. Discuss.* 1, 793–828. <http://dx.doi.org/10.5194/nhessd-1-793-2013>.
- Haddad, B.M., 2005. Ranking the adaptive capacity of nations to climate change when socio-political goals are explicit. *Glob. Environ. Change* 15, 165–176. <http://dx.doi.org/10.1016/j.gloenvcha.2004.10.002>.
- Halady, I.R., Rao, P.H., 2010. Does awareness to climate change lead to behavioral change? *Int. J. Clim. Change Strateg. Manag.* 2 (1), 6–22. <http://dx.doi.org/10.1108/17568691011020229>.
- Halder, P., Sharma, R., Alam, A., 2012. Local perceptions of and responses to climate change: experiences from the natural resource-dependent communities in India. *Reg. Environ. Change* 12, 665–673. <http://dx.doi.org/10.1007/s10113-012-0281-x>.
- Handley, J., McEvoy, D., Lindley, S., Handley, J., 2006. Adaptation and mitigation in urban areas: synergies and conflicts. *Proceedings of the Institution of Civil Engineers: Municipal Engineer* 185–191. <http://dx.doi.org/10.1680/muen.2006.159.4.185>.
- Hinkel, J., 2007. Adaptation problem types. In: *Proceedings of the Amsterdam Conference on the Human Dimensions of Global Environmental Change 2007*. Amsterdam.
- Huntjens, P., Lebel, L., Pahl-Wostl, C., Camkin, J., Schulze, R., Kranz, N., Camkin, J., Kranz, N., 2012. Institutional design propositions for the governance of adaptation to climate change in the water sector. *Glob. Environ. Change* 22, 67–81. <http://dx.doi.org/10.1016/j.gloenvcha.2011.09.015>.
- IPCC, 2007. Summary for policymakers. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., et al. (Eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge. <http://dx.doi.org/10.2134/jeq2008.0015br>. (Climate change).
- IPCC, 2014. Summary for policymakers. In: *Climate Change 2014: impacts, adaptation, and vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge and New York. <http://dx.doi.org/10.1007/BF02986817>.
- Immerzeel, W.W., Beek, L.P.H., van Bierkens, M.F.P., 2010. Climate change will affect the Asian water towers. *Science* 328 (80–), 1382–1385.
- Jiménez Cisneros, B.E., Oki, T., Arnell, N.W., Benito, G., Cogley, J.G., Döll, P., Jiang, T., Mwakilila, S.S., 2014. Freshwater resources. In: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., Mastrandrea, P.R., L.L.W. (Eds.), *Climate Change 2014: Impacts, Adaptation and Vulnerability – Contributions of the Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 229–269.
- Juhola, S., Westerhoff, L., 2011. Challenges of adaptation to climate change across multiple scales: a case study of network governance in two European countries. *Environ. Sci. Policy* 14, 239–247. <http://dx.doi.org/10.1016/j.envsci.2010.12.006>.
- Keys, N., Bussey, M., Thomsen, D.C., Lynam, T., Smith, T.F., 2013. Building adaptive capacity in south east queensland, Australia. *Reg. Environ. Change* 1–12.
- Klein, R.J.T., Schipper, E.L.F., Dessai, S., 2005. Integrating mitigation and adaptation into climate and development policy: three research questions. *Environ. Sci. Policy* 8, 579–588. <http://dx.doi.org/10.1016/j.envsci.2005.06.010>.
- Kumar, K.K., Patwardhan, S.K., Kulkarni, A., Kamala, K., Rao, K.K., Jones, R., 2011. Simulated Projections for Summer Monsoon Climate over India by a High-resolution Regional Climate Model (PRECIS). pp. 101.
- Lejano, R., Ingram, H., 2008. How social networks enable adaptation to system complexity and extreme weather events. In: Pahl-Wostl, C., Kabat, P., Möltgen, J. (Eds.), *Adaptive and Integrated Water Management*. Springer, pp. 249–262.
- Lesnikowski, A.C., Ford, J.D., Berrang-Ford, L., Barrera, M., Berry, P., Henderson, J., Heymann, S.J., 2013. National-level factors affecting planned, public adaptation to health impacts of climate change. *Glob. Environ. Change* 23, 1153–1163. <http://dx.doi.org/10.1016/j.gloenvcha.2013.04.008>.
- Liu, T., Ma, Z., Huffman, T., Ma, L., Jiang, H., Xie, H., 2016. Gaps in provincial decision-maker's perception and knowledge of climate change adaptation in China. *Environ. Sci. Policy* 58, 41–51. <http://dx.doi.org/10.1016/j.envsci.2016.01.002>.
- MEF, 2009. *Climate Change and India: Towards Preparation of a Comprehensive Climate Change Assessment*. Ministry of Environment & Forests, Government of India, New Delhi.
- MEF, 2010. *Climate Change in India: A 4 × 4 Assessment A Sectoral and Regional Analysis for 2030 S INCCA: Indian Network for Climate Change Assessment*. Ministry of Environment & Forests, Government of India.
- MST, 2010. Draft: National Mission for Sustaining the Himalayan Eco-system Under National Action Plan on Climate Change Mission Document. Ministry of Science & Technology, Government of India, New Delhi, India.
- MWR, 2011. *National Water Mission Under National Action Plan on Climate Change Comprehensive Mission Document*, vol. I.
- Mastrandrea, M.D., Heller, N.E., Root, T.L., Schneider, S.H., 2010. Bridging the gap: linking climate-impacts research with adaptation planning and management. *Clim. Change* 100, 87–101. <http://dx.doi.org/10.1007/s10584-010-9827-4>.
- Mathison, C., Wiltshire, A., Dimri, A.P., Falloon, P., Jacob, D., Kumar, P., Moors, E., Ridley, J., Siderius, C., Stoffel, M., Yasunari, T., 2012. Regional projections of North Indian climate for adaptation studies. *Sci. Total Environ.* 468–469. <http://dx.doi.org/10.1016/j.scitotenv.2012.04.066>.
- Matthews, R., Sydneysmith, R., 2010. Adaptive capacity as a dynamic institutional process: conceptual perspectives and their application. In: Armitage, D., Plummer, R. (Eds.), *Adaptive Capacity and Environmental Governance*. Springer, Heidelberg Dordrecht London New York, pp. 223–242. <http://dx.doi.org/10.1007/978-3-642-12194-4>.
- McAllister, R.R.J., McCrea, R., Lubell, M.N., 2014. Policy networks, stakeholder interactions and climate adaptation in the region of South East Queensland, Australia. *Reg. Environ. Change* 14, 527–539.
- McNeeley, S.M., 2012. Examining barriers and opportunities for sustainable adaptation to climate change in Interior Alaska. *Clim. Change* 111, 835–857. <http://dx.doi.org/10.1007/s10584-011-0158-x>.
- Merriam, S.B., 2009. *Qualitative Research: A Guide to Design and Implementation*, second ed. John Wiley & Sons, Inc.
- Mimura, N., Pulwarty, R.S., Duc, D.M., Elshinnawy, I., Redsteer, M.H., Huang, H.Q., Nkem, J.N., Rodriguez, R.A.S., 2014. Adaptation planning and implementation. In: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., White, L. (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the International Panel on Climate Change*. Cambridge University Press Cambridge, United Kingdom and New York, NY, USA, pp. 869–898.
- Moors, E.J., Groot, A., Biemans, H., van Scheltinga, C.T., Siderius, C., Stoffel, M., Huggel,

- C., Wiltshire, A., Mathison, C., Ridley, J., Jacob, D., Kumar, P., Bhadwal, S., Gosain, A., Collins, D.N., 2011. Adaptation to changing water resources in the Ganges basin, northern India. *Environ. Sci. Policy* 14, 758–769. <http://dx.doi.org/10.1016/j.envsci.2011.03.005>.
- Moser, S.C., Boykoff, M.T., 2013. *Successful Adaptation to Climate Change: Linking Science and Policy in a Rapidly Changing World*. Routledge, London & New York. <http://dx.doi.org/10.1016/j.gloenvcha.2004.12.005>.
- Moser, S.C., Ekstrom, J.A., 2010. A framework to diagnose barriers to climate change adaptation. *Proc. Natl. Acad. Sci. U. S. A.* 107 (51), 22026–22031. <http://dx.doi.org/10.1073/pnas.1007887107>.
- Mukherjee, S., Shah, Z., Kumar, M.D., 2010. Sustaining urban water supplies in India: increasing role of large reservoirs. *Water Resour. Manag.* 24, 2035–2055. <http://dx.doi.org/10.1007/s11269-009-9537-8>.
- Narain, V., 2000. India's water crisis: the challenges of governance. *Water Policy* 2, 433–444. [http://dx.doi.org/10.1016/S1366-7017\(00\)00018-0](http://dx.doi.org/10.1016/S1366-7017(00)00018-0).
- PMCCC, 2008. *National Action Plan on Climate Change*. Prime Minister's Council on Climate Change. Government of India, New Delhi, India.
- Pahl-Wostl, C., 2009. A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Glob. Environ. Change* 19, 354–365. <http://dx.doi.org/10.1016/j.gloenvcha.2009.06.001>.
- Pasquini, L., Ziervogel, G., Cowling, R.M., Shearing, C., 2015. What enables local governments to mainstream climate change adaptation? Lessons learned from two municipal case studies in the western cape, South Africa. *Clim. Dev.* 7, 60–70. <http://dx.doi.org/10.1080/17565529.2014.886994>.
- Patton, M.Q., 1999. Enhancing the quality and credibility of qualitative analysis. *Health Serv. Res.* 34, 1189–1208. <http://dx.doi.org/10.4135/9781412985727>.
- Popp, J., Mackean, G., Casebear, A., Milward, H.B., Lindstrom, R., 2013. *Inter-organizational Networks A Critical Review of the Literature to Inform Practice*.
- Prasai, S., Surie, M.D., 2015. Water and climate data in the Ganges basin: assessing access to information regimes and implications for cooperation on transboundary rivers. *Water Altern.* 8, 20–35.
- Preston, B.L., Westaway, R.M., Yuen, E.J., 2010. *Climate Adaptation Planning in Practice: an Evaluation of Adaptation Plans from Three Developed Nations Mitigation and Adaptation Strategies for Global Change*. Springer, Netherlands. <http://dx.doi.org/10.1007/s11027-010-9270-x>.
- Provan, K.G., Milward, H.B., 2001. Do networks really work? A framework for evaluating public-sector organizational networks. *Public Adm. Rev.* 61, 414–423.
- Richards, R., Sanó, M., Roiko, A., Carter, R.W., Bussey, M., Matthews, J., Smith, T.F., 2013. Environmental Modelling & Software Bayesian belief modeling of climate change impacts for informing regional adaptation options. *Environ. Model. Softw.* 44, 113–121. <http://dx.doi.org/10.1016/j.envsoft.2012.07.008>.
- Richards, L., 1999. *Using NVivo in Qualitative Research*. SAGE Publications, New Delhi. <http://dx.doi.org/10.1017/CBO9781107415324.004>.
- Saldana, J., 2009. *The Coding Manual for Qualitative Researchers, The Coding Manual for Qualitative Researchers*. <http://dx.doi.org/10.1109/TEST.2002.1041893>. (Los Angeles, London, New Delhi, Singapore Washington DC).
- Saleth, R.M., 2004. *Strategic Analysis of Water Institutions in India: Application of a New Research Paradigm*.
- Samra, J., 2004. *Review and Analysis of Drought Monitoring, Declaration and Management in India (No 84) Drought Series*. pp. 2 (Colombo).
- Sciulli, N., 2013. Organizational barriers to adapting infrastructure assets to climate change: evidence from coastal councils in Australia. *Public Money Manag.* 33, 153–160. <http://dx.doi.org/10.1080/09540962.2013.763436>.
- Sharma, S.K., Chauhan, R., 2011. Climate change research initiative: Indian network for climate change assessment. *Curr. Sci.* 101, 308–311.
- Simonet, G., Fatoric, S., 2015. Does adaptation to climate change mean resignation or opportunity? *Reg. Environ. Change* 16, 789–799. <http://dx.doi.org/10.1007/s10113-015-0792-3>.
- Smith, M., Milic-Frayling, N., Shneiderman, B., Mendes Rodrigues, E., Leskovec, J., Dunne, C., 2010. NodeXL: a free and open network overview, discovery and exploration add-in for Excel 2007/2010. *Soc. Media Res. Found.* <http://www.smrfoundation.org>, Available: <http://nodexl.codeplex.com/>, accessed 17 May 2017.
- Smith, W.J., Liu, Z., Safi, A.S., Chief, K., 2014. Climate change perception, observation and policy support in rural Nevada: a comparative analysis of Native Americans, non-native ranchers and farmers and mainstream America. *Environ. Sci. Policy* 42, 101–122. <http://dx.doi.org/10.1016/j.envsci.2014.03.007>.
- Steinberg, B., 2009. *A Network Analysis of Climate Change Non-profit Organizations in Metropolitan Boston*. Tuft University.
- Strijbos, J.W., Martens, R.L., Prins, F.J., Jochems, W.M.G., 2006. Content analysis: what are they talking about? *Comput. Educ.* 46, 29–48. <http://dx.doi.org/10.1016/j.compedu.2005.04.002>.
- Tang, Z., Hussey, C.M., Wei, T., 2009. Assessing local land use planning's awareness, analysis, and actions for climate change. *Int. J. Clim. Change Strateg. Manag.* <http://dx.doi.org/10.1108/17568690911002898>.
- Tang, Z., Dai, Z., Fu, X., Li, X., 2013. Content analysis for the U.S. coastal states' climate action plans in managing the risks of extreme climate events and disasters. *Ocean Coast. Manag.* 80, 46–54. <http://dx.doi.org/10.1016/j.ocecoaman.2013.04.004>.
- Thaker, J., Leiserowitz, A., 2014. Shifting discourses of climate change in India. *Clim. Change* 123, 107–119. <http://dx.doi.org/10.1007/s10584-014-1059-6>.
- Thampi, S.G., Raneesh, K.Y., 2012. Impact of anticipated climate change on direct groundwater recharge in a humid tropical basin based on a simple conceptual model. *Hydrol. Process.* 26, 1655–1671. <http://dx.doi.org/10.1002/hyp.8285>.
- Tompkins, E.L., Adger, W.N., Boyd, E., Nicholson-Cole, S., Weatherhead, K., Arnell, N., 2010. Observed adaptation to climate change: UK evidence of transition to a well-adapting society. *Glob. Environ. Change* 20, 627–635. <http://dx.doi.org/10.1016/j.gloenvcha.2010.05.001>.
- Vincent, K., 2007. Uncertainty in adaptive capacity and the importance of scale. *Glob. Environ. Change* 17, 12–24. <http://dx.doi.org/10.1016/j.gloenvcha.2006.11.009>.
- Wallis, P.J., Ison, R.L., 2011. Appreciating institutional complexity in water governance dynamics: a case from the murray-darling basin, Australia. *Water Resour. Manag.* 25, 4081–4097. <http://dx.doi.org/10.1007/s11269-011-9885-z>.
- Wilby, R.L., Vaughan, K., 2011. Hallmarks of organisations that are adapting to climate change. *Water Environ. J.* 25, 271–281. <http://dx.doi.org/10.1111/j.1747-6593.2010.00220.x>.
- Yohe, G., Tol, R.S.J., 2002. Indicators for social and economic coping capacity – moving toward a working definition of adaptive capacity. *Glob. Environ. Change* 12, 25–40. [http://dx.doi.org/10.1016/S0959-3780\(01\)00026-7](http://dx.doi.org/10.1016/S0959-3780(01)00026-7).
- Ziervogel, G., Downing, T.E., 2004. Stakeholder networks: improving seasonal climate forecasts. *Clim. Change* 65, 73–101. <http://dx.doi.org/10.1023/B:CLIM.0000037492.18679.9e>.



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