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ORIGINAL ARTICLE

Climate change adaptation attributes across scales and inter-institutional networks: insights from national and state level water management institutions in India

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Abstract
Effective climate change adaptation requires cohesive inter-institutional networks across different scales, facilitating the sharing of data, information, knowledge, and practices. However, the impact of adaptation attributes across scales is poorly understood due to limited focus on these networks. Based on interviews with 26 institutions operating at the national level (ION) in India and 26 institutions operating within a state (Himachal Pradesh) (IOS), this study analysed adaptation attributes and the inter-institutional networks across the two scales to understand its implications at different scales. IONs have a greater capacity (compared to IOS) to frame guidelines, standards and regulations for practitioners along with better accessibility to resources and information. When coupled with bridging institutions, this can enhance adaptive capacities at other scales. Conversely, learnings from low regret adaptive measures being implemented by IOS are opportunities for informing national policy strategies. While national adaptation strategies and goals can inspire adaptation at lower scales, the currently fragmented inter-institutional network in India reduces the passage and accessibility of data and information, creating a bottleneck for the smooth devolution of adaptation attributes. Recruitment and deployment practices for water officials further entrench silo attitudes, impeding essential data accessibility. Adaptation needs comprehensive networks across vertical, horizontal, and diagonal institutional connections to improve climate risk perception and strategy implementation. Policy measures should consider socio-institutional factors beyond legislative prescriptions.

Keywords Adaptation · Barriers · Climate change · Cross-scale · Institutions · Water

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1 Introduction

Although climate change is a global phenomenon, it is increasingly realised that adaptation needs to be addressed at multiple levels (Amundsen et al. 2010; Di Gregorio et al. 2019) by multiple sectors and actors (Vedeld et al. 2015). Institutions operating at the national level (Azhoni et al. 2017a) generally plan adaptation strategies [e.g. National Adaptation Programs of Actions: (Hardee and Mutunga 2010)] which are expected to be implemented by institutions operating at more local levels (Argyriou et al. 2012; Azhoni et al. 2017b) due to the contextual nature of adaptation (Azhoni et al. 2017b). However, the involvement of varied stakeholders in the design and implementation of adaptation measures shape its outcome (Juhola and Westerhoff 2011) due to the benefits of integrating learning experiences from local and pilot implementation projects into national adaptation policies. Therefore, institutions operating at different levels have both distinct and complementary roles in formulating and implementing adaptation strategies (Adger et al. 2005; Nalau et al. 2015) that requires interaction (Azhoni et al. 2018). Here, we define an institution as a recognised body entrusted with a particular purpose such as education, research, services delivery, administration, or policy making, and mandated by the government consisting of teams of people, rather than as 'rules and regulations' (North 1991).

Public and non-governmental institutions – including research and academic institutions – play a crucial role in enabling adaptation at multiple scales (Kirchhoff et al. 2015; Pahl-Wostl 2009) through knowledge production and exchange (Hill et al. 2020), policy making and execution (Wang et al. 2013). The characteristics of an adapting institution include the ability to recognise and evaluate the climate threats (Pahl-Wostl 2019) and accordingly make plans to either avert or take advantage of the changed/changing scenario (Jude et al. 2017) with the available resources or to acquire additional resources (Dellmuth et al. 2020). These characteristics require the availability of five key attributes.

Firstly, *awareness and accessibility to information to identify risk and vulnerability*. Accessibility to information is not just an internal characteristic of an institution if the information is being held by another institution or agency (Cvitanovic et al. 2015) so that, in a hierarchically structured system of governance, operating at the federal, state or local-level institutions will have differing accessibility to information and knowledge (Azhoni et al. 2017b) depending on their role, power or mandate. Secondly, *the availability and accessibility to resources* (human, technological and financial, in addition to information and knowledge) along with the motivation for adaptation (Månsson 2018) is necessary for successful implementation of adaptation (Engle and Lemos 2010). The availability of financial resources, for example, from climate adaptation funds, could stimulate adaptation through mainstreaming into other developmental activities (Thaker and Leiserowitz 2014). However, the ability of (regional or local) institutions to acquire the necessary resources for implementation from other national-level institutions in a hierarchically structured administrative system will also depend on their ability to articulate their vulnerabilities, need and adaptation objectives (Porter et al. 2015). Thirdly, the adoption of *high-level adaptation objectives* is expected to be championed by effective and visionary (often political) leadership (Pasquini et al. 2014) that also drives institutions through a learning process (Termeer et al. 2016) that mainstreams and iterates the adaptation actions along with other developmental activities (Thompson and Harris 2021). Such champions of adaptation, not only at the national level but within the institutions operating at sub-national or local level (Pasquini et al. 2014), can articulate the need for the required resources that will shape the adaptive capacity of the institution. For example, Van der Voorn and Quist

(2018) demonstrates how visionary leaders and their strategic visions can drive historical transitions by providing direction, inspiring stakeholders, and fostering collaboration. Vision champions are essential in creating and nurturing niches where innovative practices and policies can be developed and tested. These niches serve as experimental spaces that support broader institutional networks and enable the scaling up of successful adaptation strategies. Fourthly, once adaptation strategies and objectives have been framed, *guidance for practitioners,* particularly for institutions operating at the local level, have to be put in place and communicated to support effective implementation (Aguiar et al. 2020). Finally, *management processes* (Zollo et al. 2013) *that include effective monitoring and review mechanisms* (Ford and Berrang-Ford 2013) of the identified adaptation goals and strategy and for gaining learning experiences are required.

Given the inter-sectoral nature of adaptation (Al-Zu'bi 2016), the success of cross-scale inter-institutional coordination—across vertical (national-state-local), horizontal (inter-sectoral or inter-departmental), and diagonal (cross-scale and inter-sectoral)—is crucial for addressing climate impacts (Karhinen et al. 2021; Mukheibir et al. 2013; Street and Jude 2019). Earlier, Gupta (2007) identified the complexities of multi-level governance and the necessity for cohesive strategies and collaboration among institutions at various scales and Huitema et al. (2019) and Petrovics et al (2022) observed that polycentric governance systems enhance climate adaptation through flexibility, innovation, and responsiveness.

Several studies (e.g., Azhoni et al. 2017b, a; Azhoni and Goyal 2018; Sen et al. 2019) have, therefore, examined horizontal inter-institutional networks, but vertical or diagonal networks remain under-evaluated (Dazé et al. 2016). This gap results in limited empirical knowledge about how institutions' adaptive capacities at one scale influence another (Dazé et al. 2016). Consequently, factors causing adaptation bottlenecks and how local learning experiences can inform higher-level planning (Hill et al. 2020; Amundsen et al. 2010; Dannevig and Aall 2015; Vedeld et al. 2015) are poorly understood, despite existing studies on cross-scale dynamics (Pahl-Wostl 2009; Wyborn 2015).

In the light of the need for understanding the multi-institutional involvement at multiple scales (Duvat et al. 2021; Phuong et al. 2018), the objective of this research is to analyse the variations in climate change adaptation attributes at state and national levels and to investigate the factors and mechanisms that facilitate the transfer of these attributes through inter-institutional networks operating across scales. By examining institutions at the national level (ION) and within Himachal Pradesh (IOS), this study aims to enhance understanding of the multi-scale involvement and the role of inter-institutional networks in water management adaptation to climate change. This knowledge has wider applicability in informing water management adaptation to climate change, given the multi-scale nature of water governance and inter-sectoral competition (Bisaro et al. 2010; Pittock 2011; Wilby and Wood 2012).

2 Context and methods

2.1 Context

Water governance in India provides an ideal case for exploring the multi-layered and multiple institutional complexities associated with adapting to climate change. As per the constitution of India, State governments are responsible for administering water, but the Union (Federal) Government plays a key role in water governance because of the transboundary

nature of river basins. At the Union Government level, the Ministry of Water Resources (MWR), in conjunction with the Central Water Commission (CWC) and Central Ground Water Board (CGWB), plays the lead role in formulating national water policy and major water infrastructure development strategies and monitoring water availability and usage (Ananda et al. 2006). However, the Union Ministries of Agriculture and Power have important stakes in the development of water infrastructure, with major irrigation and hydropower projects also required to be cleared by the Union Ministry of Environment and Forest (MEF) due to environmental concerns (CWC 1998). The Union Ministry of Drinking Water and Sanitation is increasingly involved in State drinking water and sanitation services through providing infrastructure funding. The Union Ministry of Environment and Forest coordinates the climate change activities in the country but the National Water Mission (NWM), which is one of eight national missions under the National Action Plan on Climate Change (NAPCC), is implemented through the Union Ministry of Water Resources.

Parallel institutions analogous to the Union Government institutional structure exist within each State. Within the State of Himachal Pradesh, the Irrigation and Public Health Department (IPH) plays the key role in formulating and implementing the State water policy, development of water infrastructure and delivering water services. Like the Union Ministry of Environment and Forest, the (State) Department of Environment, Science and Technology (DEST) coordinates the State Climate Change activities. While State Governments are expected to align their Climate Action Plans with the NAPCC, they can adapt them to local needs due to the local nature of climate adaptation and the federal structure of the Indian Constitution (Azhoni et al. 2017b). Although this study is focussed on India, the multi-layered and multi-institutional nature of water governance that increases the complexity and interdependencies for enhancing adaptation is widely applicable in other countries and regions.

2.2 Data collection

Semi-structured interview data were collected with respondents from 26 institutions operating at the national level (hereafter referred as ION) and then 26 institutions operating within the State of Himachal Pradesh (hereafter referred as IOS), summarised in Table 1. Following a purposeful sampling strategy (Creswell 2007), all Union Government institutions involved in climate change adaptation and water management were identified through a survey of online government documents and the remaining respondents through the

Table 1 Summary of the Institutions interviewed

	Operating at national level (*n*)	Operating in the State (*n*)
Union Government Ministries (UM)	8	-
Central Government Agencies (CG for IOS and GA for ION)	5	2
Academic and research Institutions (RA)	8	3
Non-governmental and consulting (NG)	5	6
State Govt. Departments (SG)	-	10
State Govt. Departments operating at substate level (IPH)		5
Total	26	26

recommendations of other interviewees. Similarly, IOS include State Government departments (such as Departments of Environment, Science and Technology, Forests, Agriculture, and Irrigation & Public Health [IPH]); two Central Government agencies (Central Water Commission [CWC] and Central Ground Water Board [CGWB] located and operating in the State of Himachal Pradesh and non-governmental, research and academic institutions (Fig. 1). As the IPH is the primary institution for water infrastructure development and services delivery in the State and operates at State and sub-state/zonal levels, interviews were performed with representatives from all the four zones. As defined earlier, 'institutions' excludes informal and non-registered bodies and individuals, such as farmers or other water users.

The semi-structured open-ended questions (see Appendix A) were framed after wide reading of the government websites and iterated after three pilot interviews to collect data regarding the respondents' awareness of climate change, initiatives being taken, challenges and their key partner institutions. Values, beliefs and attitudes that form the core of

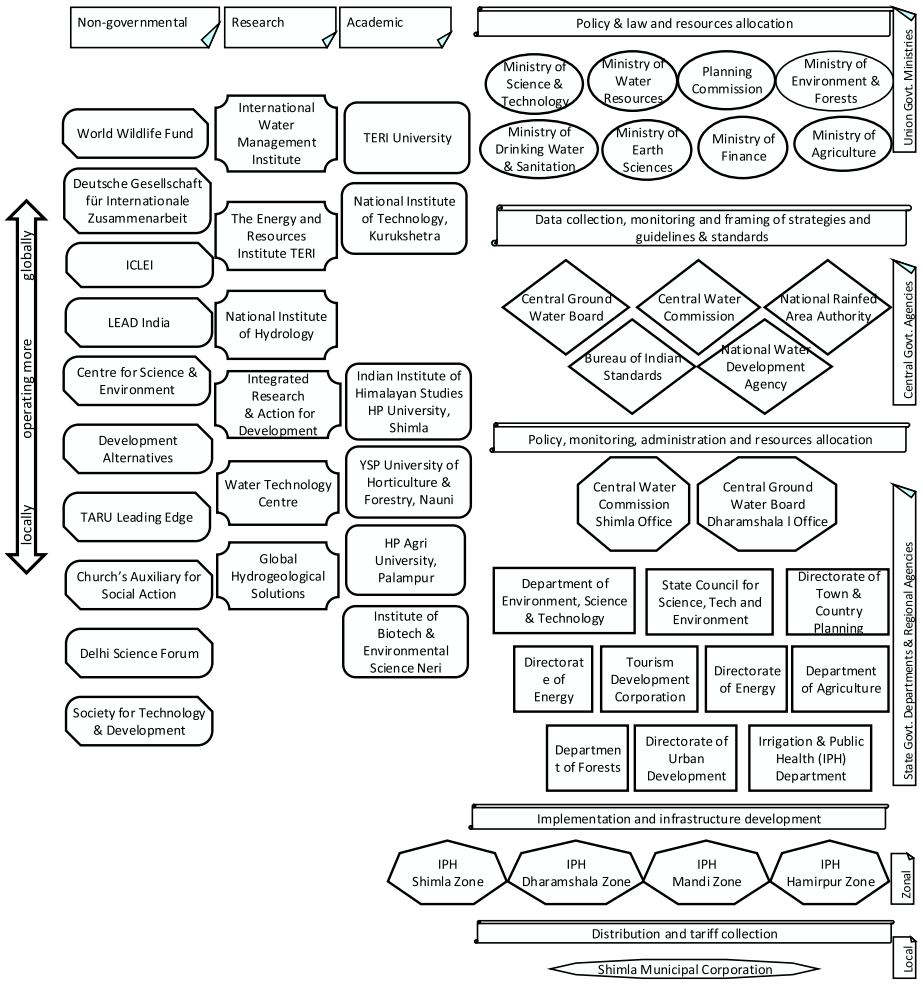

Fig. 1 Institutions interviewed and their approximate level of operation and functions

qualitative research are not normally distributed and people are not equally good at observing, understanding and interpreting their own or other people's behaviour (Marshall 1996). Therefore, meticulous identification of key informants from each of the principal institutions was an important feature in this regard. This was ensured by investigating the profiles of the interviewee from their websites which provided deeper insights into the perspectives of the principal actors in the key institutions.

The interviews ranged from 10 – 80 min, averaging 40 min depending on the response as the open-ended questions allowed respondents to address and respond a variety of perspectives as possible. Although one interview was only 10 min, it was critical in analysing the social network because it provided linkage to other key institutions. The respondents were free to deviate from the questions and the interviewer intervened only to clarify issues or probe the discussions deeper. The interviews were mostly conducted with a single respondent in their offices and audio recorded after obtaining permission and transcribed during analysis. To maintain anonymity and traceability, each participant was identified by the appropriate institutional acronym in Table 1 and a numerical figure based on the sequence of interviews conducted.

2.3 Evaluation of adaptation attributes

A thematic approach, which is a robust method for policy analysis (Braun and Clarke 2006; Fereday and Muir-Cochrane 2006), was used in analysing the semi-structured interviews. The key attributes of adapting institutions, as elaborated in Section 1, were used as the main themes for approaching the data and responses that served as supporting (or negating) the prevalence of adapting attributes at the two levels (Fereday and Muir-Cochrane 2006). Direct quotations are provided wherever possible with the intention to provide empirical evidence without the distracting use of [*sic*], with corrections [within square brackets] introduced only to shorten the quotation and/or provide clarity.

2.4 Inter-institutional networks analysis

Social structures or networks (Scott 2012) emerge from the interaction of actors (e.g. individuals, groups, institutions etc.) connected by one or more types of relationships such as common interests in a particular issue, legislation, exchange of resources, or friendships (Wasserman and Faust 1994). Social Network Analysis (Ahuja et al. 2012; Kilduff and Tsai 2003) assumes that behaviours, attitudes, influences, information or resources are transmitted between actors through such ties (Nooy et al. 2011) and provides a method for analysing relationships (Wasserman and Faust 1994).

Social Network Analysis was applied to analyse the inter-institutional networks between the institutions operating at the two governance levels. Although formal administrative structures and legislations provide the framework for institutions to relate to one another, the everyday reality of the functioning of water resources managers, users and policy makers and their behavioural interactions can be very different (Stein et al. 2011). Hence, the contextual analysis of the state or nature of interactions between these various key stakeholders becomes a necessity to understand the governance of water institutions for adapting to climate change.

The vertical, horizontal, and diagonal relationships between the institutions operating at the two scales were analysed based on the interviewees' perceived role and importance that the institutions played (or ought to play) at the State level or Union level. This was mostly

drawn from the interview question: *"According to your opinion, what is the role of the ION for enabling State institutions [or 'the role of IOS for enabling National institutions' when asked to an official from ION] to adapt and with which institutions at the national and state levels do you interact for adapting water management to climate change?*".

As data, information, knowledge, learning experiences and social practices that shape the outcome of adaptation planning and implementation, are known to flow through the networks of institutional interactions (Azhoni et al. 2017b), particular attention was focused on the network cohesion and fragmentation between the key water institutions. The dataset regarding the network analysis was generated by asking [detailed interview questions in Appendix A] each respondent "*Which institutions do you collaborate with and why? How do you build informal networks and identify key experts?*

Semi-structured qualitative interviews with key organizational leaders are effective for capturing the meaning and context of social ties, which are often missed by purely quantitative methods (Hollstein 2011). Cross and Parker (2004) demonstrate how qualitative data from semi-structured interviews can be used to uncover informal networks within organizations, providing insights into how work actually gets done beyond formal organizational charts. Likewise, Provan and Kenis (2007) explored different governance modes in inter-institutional networks, using qualitative data from interviews to analyse the structure and effectiveness of these networks. For this, leaders from different institutions who have a broad understanding of their organization's relationships and interactions are selected and semi-structured interview conducted with open-ended questions to explore the nature, quality, and frequency of interactions between institutions. Interview transcripts are used to identify and categorize the different types of relationships and interactions.

3 Findings and analysis

The findings are presented in two sub-sections analysing, firstly, whether the institutions operating at the two different scales exhibit the attributes of adaptation and secondly, the horizontal, vertical, and diagonal relationships within the institutional networks. To anonymize personal identities while maintaining traceability, responses are coded with two letters and two digits to represent the type of institution and a serial number (e.g., UM for Union Ministries, CG for Central Agencies, SG for State Departments, NG for NGOs, RI for Research Institutions, AI for Academic Institutions, and IP for Irrigation/Public Health zonal branches), as shown in Fig. 1 and Table 1 above.

3.1 Attributes of adapting institutions: do Indian institutions have them?

The prevalence or lack of adapting attributes within institutions operating at national and state level are tabulated and compared in Table 2 and each of the adapting characteristics are further elaborated and discussed.

3.1.1 Awareness and ability to identify climate risks and vulnerability

There is arguably general acceptance of the changing climate among respondents from both ION and IOS, albeit from different perspectives. The ION respondents mostly relate to climate change impacts in terms of vexing the overall situation (e.g. *"climate change is going to aggravate the situation"* [UM03]) in contrast to the IOS respondents who relate to

Table 2 Evidence for the prevalence and absence of attributes of adaptation within water management institutions operating at National and State levels: exemplar interview quotes

Attributes	National	State
a. i. Awareness and access to information	*"Aware, but not sensitized enough."* (AI06)	*"Our State Government is very much aware of climate change"* (RA21) *"but … might not be of that level so that can make changes."* (SG10)
ii. Ability to identify risk and vulnerability	*"References are there but detailed study is not there under the climate change scenario."* (RI07)	*"As on date, the impacts have not been studied or structured in detailed manner."* (IP08)
b. i. Access to resources	*"There are some issues … many departments are not willing to share the data."* (RI17)	*"Here we do not have the knowledge and human resources. They are the major hurdle."* (IP08)
ii. Motivation for adaptation	*"There have been some additional funds…* [which] *is for climate change adaptation but at the end of the day it is also meant for development."* (NG10) *"We have to follow a little cumbersome procedure. That's a deterrent."* (RI17)	*"There is no such budget in my department … Neither there is any assurance nor there any encouragement* [for knowledge acquisition]*."* (IP02)
c. i High level adaptation objectives	*"National Water Missions has very right goals for adaptation …"* (GA01)	*"We have … very good State Strategy on climate change that includes water also."* (SG09) *"The Government of HP in line with the Central Government initiative …is implementing almost all the national missions." (AR24)*
ii. Effective and visionary leadership	"*One missing link is … leadership. … who are genuinely interested …cannot be only through speeches."* (RI17)	*"We are not clear about what practically can be done."* (SG10) *"Government should make some statutory authority* [with] *leading experts and whatever they write …plan …think, should be implemented."* (IP02)

Table 2 (continued)

Attributes	National	State
iii. Low regret anticipatory measures	*"Very recently… organised one seminar on … incorporate*[ing] *climate change aspects in analysing probable maximum flood* [and]*… design of irrigation infrastructure to accommodate the impact of climate change. … on the other hand we have this criteria of 75% dependability for planning of the irrigation projects… we are thinking to decrease it to 60 or 50% dependability so that the variation of the climate change can be accommodated."* (GA01)	*"Earlier, for providing drinking water our focus was … to find the nearest source."* (IP02) *"We are now taking from… perennial bigger sources, where the impact is on the lesser side."* (IP01) *"…in every Govt. building, or even the private buildings, the rainwater harvesting is compulsory. In commercial buildings now it is compulsory to have the double plumbing system."* (AR24)
iv. Organisational learning and mainstreaming	*"Government systems are mammoth systems and…* [laughs] *…it takes time for those things to be materialised."* (GA01) *"Earlier water is …*[understood] *only in terms of irrigation. But now we are looking at water in a holistic manner."* (UM02) *"They* [Government agencies] *still think that it is more of a hungama* [commotion] *and alarm but their first priority is to meet the demand and supply gap."* (NG09)	*"The government set up is such that adaptation takes long, long time."* (IP02) *"I think we are much aware now of the problems which we are likely to face. … So now we don't go for short term projects. We go for long term plans. May be it is not cost effective today. But we see after many years it will be sustainable. So that things have definitely changed. … We are now planning for twenty thirty years."* (IP03)
d. i. Guidance for practitioners	*"I think there are frameworks of climate change adaptation guidelines which are coming out and I am one of the members."* (RI11) *"We already have standards for earthquake designs… but we do not have any standards related to climate change yet."* (AI06)	*"The major hurdle is that the impacts are of such a general nature that we cannot take specific action."* (IP08) *"We are not clear about what practically can be done."* (SG10) *"Guidelines and policy are not there to adapt in water management, only then I can implement it. … We have to evolve some mechanism to incorporate these impacts of climate change on water resources."* (IP07)

Table 2 (continued)

Attributes	National	State
ii. Effective communication of risks and opportunities	*"We have formal meetings quarterly, half yearly, yearly, depending upon the requirement we keep meeting them."* (UM02) *"This is a process that we are evolving."* (GA01)	*"I think climate change is being dealt by the Science and Technology Department. Whenever they plan some workshop or some deliberations, they definitely call us. From here, there is no specific Nodal Officer or a wing which looks after it."* (IP07)
e. i. Management processes	*"We are in a kind of… neglect and rebuilt…. our paradigm has been to build ….do not manage it properly… deteriorated and then we rebuild… This has been happening and we didn't have proper institutions to manage them effectively and properly…we have to … improve …the management."* (RI04)	*"You have one idea when you are not into the system. … another when you are inside… Outside … everything is doable. In the system you have so many bottlenecks. That, at the end of the day you'll say, just forget it."* (NG18)
ii. Monitoring and reporting progress	*"There was a … hydrologic project. One of the objectives was to review the networks* [of rain gauges] *and …*[identify] *…the duplicacies and … missing stations or protocols … and then redesign the whole network. …But subsequently the follow up was not up to the mark, up to the level that it should have been."* (RI17)	*"Actually, all these things are being done in a piecemeal manner –something here …"* (IP07)

the changing climate through their everyday experiences: *"climate change indicators are very clear over here"* (AR05) and *"depletions in water sources …is mainly attributed to the climate change"* (IP01). Some ION respondents identified that government agencies, particularly at the State level, are *"not …sensitised enough in terms of the threats"* (AI06) and *"the States and the line agencies* [State Government departments] *on the ground … are not really aware about the challenges itself."* (RI11). This was corroborated by an IOS respondent: *"as on date, the impacts have not been studied or structured in detailed manner"* (IP08) which partly arises from the State water infrastructure development agencies being at an early stage of collecting hydrological data to understand the long-term trends. This was stated by one respondent: *"Actually all these things are being done in a piecemeal manner …data acquisition and some awareness program* [are at initial stages]*…"* (IP07) and hence are yet to initiate incorporating climate risk factors into infrastructure planning and design.

Although a researcher from an IOS stated that *"vulnerability index…* [to] *see how in the near future … the increase in temperature would happen"* (AR05) and assessments *"to find the different indicators of climate change"* (AR05) are being developed, many IOS respondents, such as IPH, are unaware of impact studies carried out by other agencies or research institutions. Consequently, they find the State-specific impacts to be unclear and a primary challenge to plan or implement adaptation strategies: "*the major hurdle is that the impacts are of such a general nature that we cannot take specific action."* (IP08). Therefore, although there is a general acceptance that climate is changing, the details regarding its impact and consequential actions that need to be taken are largely unidentified, unclear, or ignored by water infrastructure agencies.

3.1.2 Access to resources and motivation for adaptation

Most of the respondents related resources mainly to financial, technological and human rather than natural or physical when discussing availability and accessibility. For many respondents, both from ION and IOS, the lack of resources was a key dissuasion for adaptation: *"resource is a major constrain"* (RI04); *"financial support is also not forthcoming as well as at the right time"* (GA01) and *"it is not possible with the limited infrastructure"* (GA12). However, many specifically referred to inadequate human resources, particularly at the implementation field: *"we do not have barefoot hydrologists"* (AI06); *"The government is not replacing whatever the retirements are happening"* (IP03) and *"How can I be the only to collect data from field, monitor and analyse"* (SNG25). This concern was not, though, constrained to staff numbers: "*at the moment software* [skill and motivation] *is more important than the hardware* [infrastructure or technology] *… the kind of knowledge has to … sink in"* (RI11) and therefore, *"the important thing is capacity … of the agencies"* (RI11). However, the inaccessibility of data and information is a major difficulty reported by both ION and IOS. Lengthy bureaucratic protocols, hindrances to forming partnerships with other (especially overseas) institutions, and the absence of a system that encourages and incentivises learning, were major demotivating factors for many of the respondents.

For many respondents, the motivation for adaptation comes from the hope that it will also improve the current water infrastructure and management if mainstreamed into development. For example, a respondent observed: "*with this climate change… attention of the people, policy makers, decision makers have been there on more serious notes. … the* [water] *sector is given attention … this will turn into more and better systems…"* (GA01). The current attention to climate change is an opportunity to highlight "*the deteriorating*

and inadequate water infrastructure" (GA01) so that decision makers allocate additional resources: *"there have been some additional fund. … The funding is for climate change adaptation but at the end of the day it is also meant for development."* (NG10).

3.1.3 High level adaptation objectives, visionary leadership, low regret adaptive management and organisational learning and change

Improvement in water use efficiency to reduce water demands and increased reuse of water are key objectives expected to be brought about through climate change adaptation actions, such as National Water Mission: "*…if you improve the water use efficiency, which is anyway required because of the sectoral increase in competing demand, will anyway benefit or aid adaptation in the climate change"* (RI11). Most low-regret adaptive management are aimed towards meeting supply demand, rather than reducing flood and drought risks, with most aimed towards water users rather than adoption by water management institutions themselves.

Organisational learning involves a flexible structure and a system that encourages its personnel to experiment and innovate. At the individual level, some respondents pointed out that this was not there. However, there have been significant changes in the water management in India over the past few decades associated with revisions to the National Water Policy in 2002 and 2012 (MWR 2012, 2002). When asked about these changes some respondents believe that the change is *"…not on a smaller time scale* [but] *yes on a longer time scale say, last thirty years fifty years.* [Earlier]*… we had sufficient amount of water. The population was less. But … climate is changing … this only has resulted in the formation of these eight National Missions. So there is a more focus from the government side towards these climate change impacts."* (UM18).

When asked about these changes within the government institutions, there were mixed reactions. Some respondents believe considerable change has occurred, but not necessarily driven by climate change alone (UM18): "*we now are looking water as a resource… and* [realising] *it is a limited resource. So that is the reason we want to use the water more efficiently.*" (UM02). Others added that although individuals in the government recognises the changing scenario, *"Government systems are mammoth systems and …*[laughs] *…it takes time for those things to be materialised … The pace is not that fast … Nevertheless, the thinking is there…changes are there."* GA01). While on the other hand, another regrets: "*No, unfortunately not"* (NG15).

Others pointed out to the more stringent regulation of groundwater as an indication of change:

> *"There are so many changes… One is in the shape of regulations. Certain things like ground water which was anybody's baby; anybody could dig a well and start pumping and take it as per requirement. Those things have changed. Because of this the government has realized this has to be regulated. So regulatory part of the government is more noticeable now"* (IP06).

3.1.4 Availability of guidance for practitioners at the point of use

Standards and guidelines for improving water use efficiency that incorporate climate change factors into water infrastructure planning are being developed, although "*we do not have any standards related to climate change yet"* for mega water infrastructures (AI06).

However, *"…there are frameworks of climate change adaptation guidelines … coming out and I am one of the members …"* (RI11) and *"one of the adaptation strategies* [is to develop Indian Standards such as the ISO 14090:2019 Adaptation to climate change — Principles, requirements and guidelines] [for which] *I am going for a meeting …with BIS"* [Bureau of Indian Standards] … *"We do not have an Indian Standard …"* (NG09). To improve water use efficiency; *"new institutional mechanism…* [through the] *National Bureau of Water Efficiency…"* (UM02) are being created and Indian Standards are being developed to guide and evaluate water use efficiencies (NG09).

Water engineers from IOS cited the non-availability or generalised nature of such national guidelines as a key barrier for incorporating climate change risk factors into their planning and design of infrastructure: *"… guidelines and policy is not there to adopt then how I can comment on the challenges for successful implementation"* (IP07) and *"There are some guidelines which are made generally for the entire city* [for example] *that do not keep in mind the hill states"* (SG11). Consequently, *"Until and unless very specific end action plans are given for particular area…… then only it is possible to tackle the climate change"* (IP08).

In contrast, other respondents recognised the need to build the capacity of institutions and individuals operating at the State level (RI17, RI11) so that they can take their own specific local challenges into account in decision making their own specific:

"*there are bodies with expertise, technical expertise, they can prepare broad blueprints but which of course need to be understood and modelled to suit local …by the state governments and their respective institutions,"* what is required is *"… to build proper capability, in order to get it done correctly…* [depending on] *… local needs."* (NG15).

There were mixed perceptions of the communication channels at the Union Government. At the State level, effective channels of communication between and within different government departments were less apparent. Many respondents were unaware of the State Action Plan on Climate Change, with effective communication from the Nodal Officers to other personnel within the same department not being visible. A major causative hindrance to the passage of information and coordination was the transfer of officials, with short notice, and the failure to communicate such changes to other departments.

3.1.5 Management processes for monitoring, reporting of progress and evaluation

Respondents at National and State levels identified that many important projects are not implemented adequately due to lack of effective management processes and weak monitoring. A respondent cited an example of this ineffective follow up:

> "*One of the objectives* [was] *to review the networks and find out … the duplicates and where the missing stations or protocols or something and ... redesign the whole network. They did that also. But subsequently the follow up was not up to the mark, up to the level that it should have been."* (RI17)

Others pointed out the poor management of existing infrastructure.

> *"… we are in a kind of … neglect and rebuilt… our paradigm has been to build certain things ….do not manage it properly… deteriorated and then we rebuild… this has been happening and we didn't have proper institutions to manage them effectively and properly so if we want to make very good use of these structures or these kinds of infrastructures which helps in adaptations… then we have to improve the software part of the management"* (RI04)

Given that climate change adaptation in the State is at an early stage, it is especially important that monitoring and evaluation is embedded into the adaptation strategies in order to benefit from the learning experiences as well as ensure compliance. Since effective monitoring and evaluation of adopted adaptation strategies is also dependent upon the interactions between institutions operating at different scales of operation, and the networks of coordination, the following subsections address the existing structure of interactions.

3.2 Interaction between institutions at different scales

The importance of a vertical and diagonal coordination between the State Government departments and Union/Central Government agencies, in addition to horizontal cross-sectoral relations, was acknowledged by most respondents. However, ensuring this coordination among the different institutions is a major challenge in operationalising the adaptation strategies being planned by the institutions operating at the national level and the State Centre on Climate Change in Himachal Pradesh. The need for converging programs, such as water conservation and rural employment schemes which are being implemented through different agencies, and linking with climate change adaptation was emphasized:

> *"Government should set a nodal institution which can coordinate with different institutions so that everybody work in tandem and there is a perfect coordination. We can exchange our views, exchange our data, what steps, what contingent plans we need to adopt and how we implement it. There must be some nodal authority who can coordinate with all the stakeholder."* (IP02)

There is considered no shortage of research in India (RA24) but the weak relations between the institutions operating at the national level and the State level and between the policy-making bodies and the implementing agencies means that there is an important need to build the knowledge capacity of implementing agencies, such as the State water institutions.:

> *"We have high level research institutions like IWMI* [International Water Management Institute] *or IIT* [Indian Institutes of Technology] *or ….NIH* [National Institute of Hydrology] *….and they have important findings and bearings ….and then we have local level agencies …to help people adapt but they require knowledge …*[and] *technologies …Since the government agencies …providing that link is quite weak …there is no flow of the information from the upstream to downstream"* (RI04).

From the interview responses collected, some of the key roles the respondents from IOS expect from the ION can be summarised as a) funding, b) capacity building, c) conflict resolutions, d) international mediation, particularly in transboundary basins, e) information and data gathering and dissemination, f) a nodal institution that brings together different sectors and institutions, and g) formulation of policy regulations and guidelines. Many of the engineers believe water should become a central subject instead of the current state subject because they believe that will ease the inter-state water conflicts and improve water management.

3.2.1 Inter-institutional relations

Figure 2 shows the identified inter-institutional network based on the specific interview question "*Which institutions do you collaborate with and why?"*. The direction of the

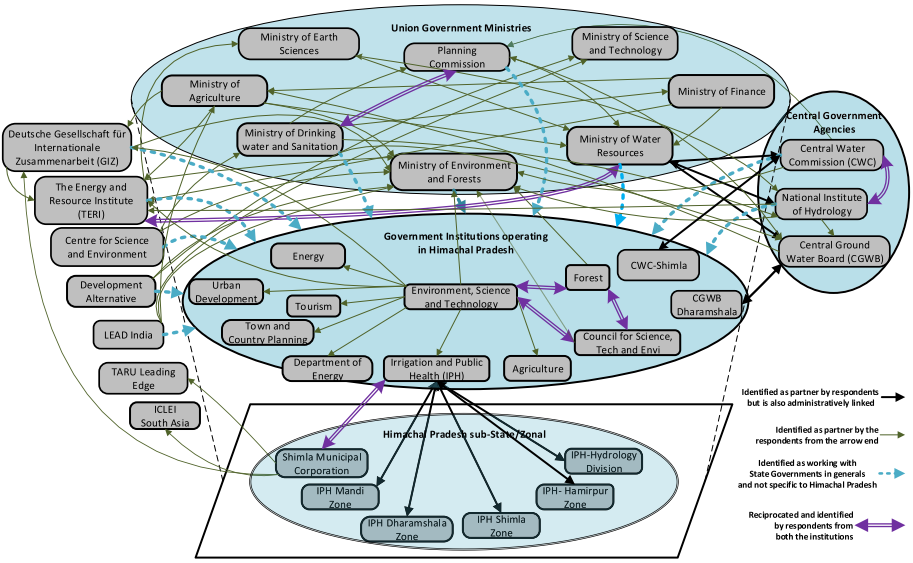

Fig. 2 Institutional relations as derived from interviews with representatives from each of the institutions

arrows in the figure point to the institutions that the respondents referred as their partner institutions. The reciprocated relations between two institutions are indicated in double arrowed lines while the institutions that stated to be working with State governments in general (and not specifically with Himachal Pradesh Government alone) are indicated in dotted lines. Institutions connected by virtue of administrative setup are indicated by thick lines in Fig. 2.

Of the eight Union Government Ministries interviewed, only four stated that they worked with State Governments in the context of water management and climate change. These are the Planning Commission and the Ministries of Drinking Water Supply and Sanitation, Environment and Forests, and Water Resources. The National Institute of Hydrology and Central Water Commission, both of which come under the Ministry of Water Resources, also stated as working with the State Governments. From among the non-governmental consulting and research institutions, The Energy and Resources Institute (TERI) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) were acknowledged by both the Central Government Institutions and State Government departments, in contrast to others, such as the Centre for Science and Environment and Development Alternatives, who stated that they work with the State and Union Government Institutions but were not mentioned by the State respondents.

The inter-departmental relations in the State are highly centralised, with DEST at the centre, as Fig. 2 shows. In Himachal Pradesh, since the Department of Environment, Science and Technology (DEST) coordinates the formulation and implementation of the State Action on Climate Change, it interacts with all other state government departments where Nodal Officers for State Action Plan on Climate Change have been appointed. However, the relationships are largely one-way information dissemination, with the exception of the Forest Department and the State Council for Science, Technology and Environment (SCSTE) with whom they have frequent interaction and have higher knowledge of each other's work. These three institutions alone, from among all the State Government Departments, have

direct access to a Union Government ministry – Ministry of Environment and Forest. A similar reciprocated relation is reported between the Municipal Corporation and the IPH.

The respondent from Central Water Commission (CWC) at the Head Office in Delhi emphasized the importance of the State Government departments in adapting water management and how their institution is working with the latter in capacity building. However, the CWC respondent at the regional Himachal Pradesh office did not indicate a close relation with the State Water Department (IPH) and instead indicated only a reactive approach in sharing of hydrological data: *"Some format and procedure is there … to get these data. We are just seeing the justification. Anybody can ask the data but based on the requirement … we are providing the data"* (CG12). The State government agencies on the other hand mentioned the difficulty of accessing (hydrological) data from Central Government agencies:

> *"Nobody wants to share the data. We had memorandum of understanding, with various other organizations for sharing of the data… in spite of this actual transfer of data is not smooth. You have to make real efforts to get these kinds of information. It is a big challenge although all the departments are government departments"* (IP06).

Interaction of the State Government institutions with academic and research institutions in Himachal Pradesh was limited except for a strong working relation between the Department of Agriculture and the HP Agriculture University, Palampur for dissemination of climate information to farmers.

4 Discussion

From the results elaborated in Section 3, three insights can be drawn in relation to climate change adaptation for water management at multiple scales. Firstly, institutions operating at different administrative scales with different spheres of mandate or involvement can contribute to enhancing the adaptive capacity of institutions operating at another scale. Secondly, removing or overcoming the bottlenecks of inter-institutional networks is essential for adaptation across scales. Thirdly, institutions collaborating with institutions/agencies at different scales can help bridge the gap between institutions operating at those scales and the role played by such institutions need to be recognised.

4.1 Variable and similar adaptation attributes and barriers across scales

Comparisons of the perspectives of the respondents from institutions operating at the national level (ION) with those at the state level (IOS) indicate a broad awareness across the two scales but apparent greater awareness among the respondents from ION, possibly due to better accessibility to information. However, the awareness is not accompanied by the ability to identify local specific risks and vulnerabilities hindering the identification and implementation of local specific adaptation strategies, unlike mitigation (Azhoni and Goyal 2018) and highlighting the need for capacity building of IOS (and other local bodies).

The availability and accessibility of resources motivates institutions to articulate and adopt adaptation strategies. A nation's wealth, education, technology, infrastructure and information are often considered for measuring national adaptive capacity to climate change (Berrang-Ford et al. 2014; Eisenack and Stecker 2012; Pahl-Wostl et al. 2010) but, as the findings in this study indicated, the aggregated national wealth cannot be assumed

to result in increased adaptive capacity at the local level. The responses in this study shows that the availability of resources, particularly in the form of additional budgetary allocations that provides the National and State institutions with the opportunity to improve the water infrastructure, is an important motivation for articulating adaptation needs. This largely reflects the attitudes in developing countries that face acute inadequacies in the current requirements for water infrastructure (Pasquini et al. 2013; Rosendo et al. 2018). Responses from the IONs indicate a higher interest for adaptation due to the perceived opportunities for improving the overall water infrastructure, in addition to combating the climate change risks, with the additional funding (although it may or may not be framed as adaptation funding). This emphasises the need for mainstreaming adaptation into other developmental activities (Sharma and Tomar 2010), particularly in developing economies. Motivation drives actors beyond the requirements of rules and legislations and hence is an important factor in enabling adaptation (Ekstrom and Moser 2014).

On a positive note, the high level adaptation objectives through the National Water Mission (MWR 2011) under the National Action Plan on Climate Change (PMCCC 2008) being complemented by the State Strategy and Action Plan on Climate Change (SSAPCC) (DEST-HP 2012) is a strong incentive towards adaptation, as suggested by other frameworks of assessment (Wilby and Vaughan 2011) and reviews (Bizikova et al. 2015). The objective of framing the NAPCC was such that State governments will be able to extract the relevant goals and 'dovetail' the implementation.

While respondents from IOS reported the lack of impact studies to inform them of potential risks and vulnerabilities, respondents from ION indicated these studies are being initiated, showcasing the latter's higher adaptive capacity, likely due to better access to information. This gap highlights the need to identify mechanisms for 'transferring' capacities to the local level to enhance adaptation efforts. Inaccessibility to resources, including information and technology, can demotivate adaptation efforts and create barriers (Cvitanovic et al. 2015). Given that the ability to identify risk and vulnerability is a key determinant of adaptive capacity (Engle and Lemos 2010), respondents from research ION emphasized the need for capacity building of IOS. Additionally, the study by Van der Voorn et al. (2017) underscores the importance of robust adaptation planning through coordinated inter-institutional networks. Their findings on the comparative evaluation of adaptation strategies across different coastal regions offer valuable lessons on enhancing collaboration and information sharing across scales. Adaptation guidelines initiated by ION need to be effectively communicated to IOS, as respondents from IOS identified the lack of such guidelines as a key challenge in incorporating climate change impacts into their systems. Addressing these issues through improved inter-institutional networks can foster more effective and resilient climate adaptation strategies.

4.2 Inter-institutional network challenges

Since the institutions operating at different scales have different roles and responsibilities, they require different capacities to adapt to climate change. Nevertheless, certain traits of adaptation such as the ability to identify climate risks, access to information and knowledge and the capacity to plan adaptation strategies at their level are required. As accessibility to data and information was repeatedly highlighted as a key adaptation barrier by many respondents, inter-institutional networks among the key water institutions (Fig. 2) were evaluated. In this study, Social Network Analysis assessed why variations of adaptive capacity exists across scales and if such attributes can be transferred through

inter-institutional networks. A notable absence of horizontal networks between the institutions operating at the sub-state/zonal level can be observed in Fig. 2. This is largely due to the administrative setup whereby the linkage is provided through the head office operating at the state level although no intentional administrative barrier exists by design.

While previous studies have pointed out the challenges of data accessibility in India and the need for greater coordination across scales (Azhoni et al. 2017b), this study suggests that the way officials are recruited and posted contributes towards weak inter-institutional networks. Contrasting the cross-scale relationships between the four key water institutions with that of the four environment institutions in Fig. 3 provides insights regarding the silo-attitude between the water institutions in India. There are weak links between the State Irrigation and Public Health Department and the two Union Government agencies; Central Water Commission and Central Ground Water Board, even though they all operate within the same geographical area, Himachal Pradesh. In contrast, the DEST, CSTE and the Forest Department in the State have close coordination between them and with the Union Ministry of Environment and Forest. The doted arrows in Fig. 3 indicate the links that require stronger coordination to improve exchange of data, information, knowledge and learning experiences that ultimately leads to greater adaptation implementation (Jolink and Dankbaar 2010). This difference in cross-scale networks between the water and environment institutions can partially be explained by the differing way their officials are recruited and deployed. The officials in the four Environment Institutions are recruited through the same administrative process (Indian Forest Service) and have the mobility to move from one institution (department or ministry) to another (vertically from State to Union and vice-versa and horizontally from one department to another). In contrast, the water officials are recruited through four separate processes and are posted within the same institution into which they have been recruited, except the bureaucrats in the Union Ministry of Water Resources who are from the Indian Administrative Services. Therefore, a structural silo has been introduced into the system through the way the water cadre is recruited. Restructuring the recruitment and deployment processes in the water cadre in India along the lines of

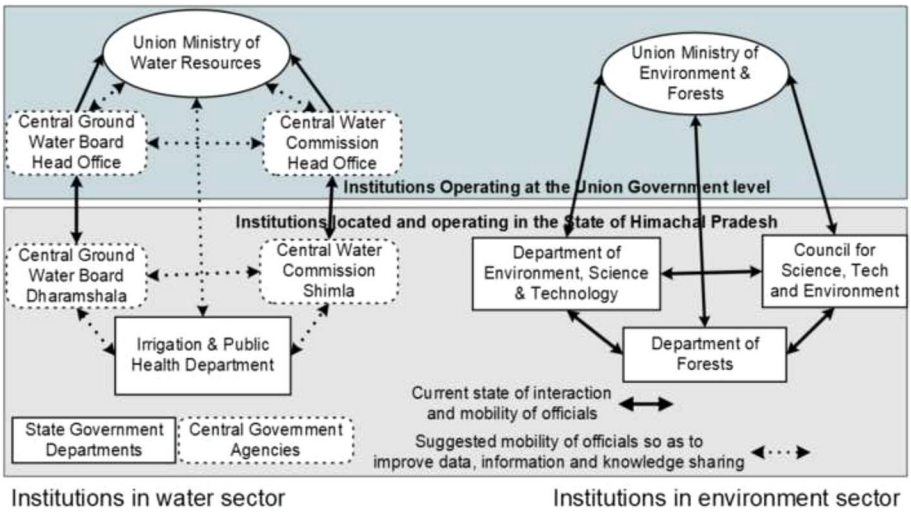

Fig. 3 Comparison of the conceptualized mobility (through recruitment and deployment) of officials between the institutions in water sector and environment sector

Indian Forest Service (IFS) could be one possible solution to improve mobility and eventually coordination between the water institutions.

4.3 Bridging institutions

In addition to the inter-institutional networks between government institutions, the network analysis shows the key role being played by bridging institutions. Bridging institutions act as connecting links between different sectors and institutions operating at different scales (Kiem and Austin 2014; KimDung et al. 2016) and broker knowledge and information (Hill et al. 2020) in addition to acting as the passage through which the learning processes occur (Karhinen et al. 2021). In this study, the critical role these bridging-institutions (such as TERI and the Centre for Science and Environment) are playing in not only providing the connecting link between government institutions operating at National and State levels but also in knowledge generation and dissemination of information is observed. Similarly, other non-governmental organisations such as the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and TARU Leading Edge work with many State government departments as well as Union Government Ministries. Other studies, such as (Wyborn 2015), have shown how the absence of brokers and/or structural linkages between different arenas of governance constrained the adaptive capacity and how broader socio-political contexts shape its capacity to coproduce knowledge. The key role played by such institutions identified in this study needs to be highlighted because their active involvement enhances the adaptive capacity and broadens the bottlenecks between the institutions operating at the national and State level.

4.4 Reflections on the methodological approach and data

As observed from literature (Marshall 1996) and highlighted in Section 2.3, the values, beliefs and attitudes of the respondents – which form the core of qualitative research – varied widely. Respondents are also not equally good at observing, understanding or articulating their own or other people's perspectives/behaviour (Marshall 1996; Mills et al. 2006; Saldana 2009). Their responses corroborate these earlier observations on qualitative studies as quotes from certain respondents appear more often than others and some interviews were much shorter (ranging from 10 to 80 min). This is largely due to variations in their capacity to clearly articulate their observations and because of their roles and experiences in their respective institutions – let alone their individual nature, educational qualifications, and overall outlooks towards societal concerns such as climate change or water. Since the aim of the study was not necessarily to give equal voices to all the respondents from a variety of institutions but to identify specific responses that corroborates the themes elaborated in Section 1, the quotes have been deliberately selective. This should not be seen as skewing the findings of the study. Rather it brings out un-anticipated insights which is a goal of exploratory research (Moallemi and Malekpour 2018). Moreover, while one interview was much shorter than the average (40 min), it served the purpose in identifying the inter-institutional networks and enabled to complete the network perspective.

While semi-structured interview approach can introduce bias and variability in the data, as it relies heavily on the subjective interpretations of respondents, divergent perspectives collected from a variety of institutions operating at different scales providing multiple services enriched the findings. Nevertheless, the study's sample size, comprising representatives from 26 national and 26 state-level institutions, may not fully capture the diversity

of perspectives across all relevant institutions. Expanding the sample size and including a broader range of institutions could improve representativeness. Additionally, employing stratified sampling techniques can ensure that key sectors and levels of governance are adequately represented.

In addition, cultural and contextual differences can affect how respondents interpret and respond to questions about climate adaptation and inter-institutional networks. One of the authors being an experienced former scientist in the Government who understand the cultural contexts greatly improved the relevance and accuracy of the data collected. Nevertheless, analysing inter-institutional networks involves complex relationships that may not be fully captured through qualitative interviews alone. Complementing qualitative data with quantitative social network analysis (SNA) can provide a more comprehensive understanding of the networks. SNA can help visualize and quantify relationships, revealing patterns and key actors that qualitative data might miss.

The study's snapshot in time may not account for the dynamic and evolving nature of inter-institutional networks and climate adaptation practices. Conducting longitudinal studies can provide insights into how these networks and practices evolve over time. Regular follow-up interviews and data collection points can track changes and adaptations in response to emerging challenges and opportunities. By reflecting on these limitations and implementing strategies to address them, the study can enhance its methodological rigor and provide more robust, comprehensive insights into the inter-institutional networks supporting climate change adaptation.

5 Conclusion

This study illustrates that institutions operating at the national level have the potential to create adaptation enabling opportunities for institutions operating at the lower scales that are implementing national strategies or developing and operating water infrastructure. It also demonstrates that the low regret adaptive measures being adopted by local level institutions can provide important insights for planning adaptation strategies by institutions operating at the national level and beyond. While national adaptation strategies and goals can inspire adaptation at lower scales, Social Network Analysis of the cross-scale inter-institutional networks identifies bottlenecks between various institutions operating at different scales. The associated inter-institutional fragmentation reduces the passage and accessibility of data and information and the sharing of knowledge and learning experiences can limit the adaptation enabling factors and the identification of adaptation opportunities. Our ability to understand adaptation by water institutions depend on factors beyond the commonly used adaptive capacity indicators such as national wealth, technology, human and natural resources, among others. Aggregated national indicators cannot be assumed to indicate increased adaptive capacity at local levels. It requires the understanding of institutional structures and the vertical, horizontal and diagonal social networks between officials in different government institutions and factors that affect perception of climate change risks, opportunities and the implementation strategies. Bureaucratic processes of recruiting key officials, although seemingly having nothing to do with climate change adaptation, are shown to indirectly influence adaptive capacity of the country through an improved network of coordination among key officials. The study demonstrates

that such factors outside of a particular institution, including the role played by bridging institutions and institutions at another scale of governance, strongly influence an institution's ability to address climate change impacts on water management. Studies on the nature and role of vertical and diagonal networks in other socio-political and environmental-economic contexts, particularly where the institutions are loosely connected administratively, will provide further insights on creating conducive adaptation enabling institutional designs for addressing the increasing concerns of climate change impacts on water governance.

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Author contributions All authors contributed to the study conception and design. Material preparation, data collection, analysis and the first draft of the manuscript was written by the first author and all authors commented and edited on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability Data underlying this study can be made available on request to the corresponding author.

Declarations

Competing interests The authors have no relevant financial or non-financial interests to disclose.

Appendix A: Interview questions

1. Can you tell me briefly about your organization and your role within the organization in relation to climate change adaptation and water?
2. What is your view on climate change?
3. Do you think that climate change presents serious risks to water management challenges in India?
4. What adaptation strategies or actions your department/institution is involved in to address climate change impacts for water management?
5. Why did your institution initiate these actions? Is it because you got some specific directive/instructions about the need to initiate these actions by the state or central government?
6. How is your ministry/department/organisation involved in the NWM/State Strategy & Action Plan on Climate Change?
7. Are you being informed of the strategies/action being planned and initiated at the national/state level?
8. What specific inputs were sought from your department regarding this? Have you received any specific guidelines to incorporate climate change factors into your planning and designing of water infrastructures from the State or Union Government?
9. How do you and to which ministry/department do you report about the implementation of these adaptation strategies?
10. Which other organisations, departments, ministries, consultants, NGOs, research institutions do you work with in connection to climate change adaptation for water management?
11. Why do you work with them?
12. What are the kinds of support you get from them?
13. What kind of support do you give them? What are the challenges of working with other departments, institutions?
14. What do you think is the role of the Union/State Government in the adaptation process and how do you liaise with them?
15. What are the main challenges for successful climate change adaptation for water management in Himachal (or your zone or district)?
16. What kinds of resources do you think is required for climate change adaptation in water management and who provides them?

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