Environmental Management (2019) 63:233–248
https://doi.org/10.1007/s00267-018-1128-0

Analyzing Social Networks to Examine the Changing Governance Structure of Springsheds: A Case Study of Sikkim in the Indian Himalayas

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Received: 9 April 2018 / Accepted: 2 December 2018 / Published online: 12 December 2018

Abstract

The governance of natural resources now attracts greater participation of different stakeholders, ushering in a shift from conventional governance by the state to that by a network of stakeholders—a form of governance marked by a growing role of non-state and local actors. These changing dynamics are highlighted through a study of the governance network for springsheds in the Indian Himalayas by empirically mapping the changes in the *Dhara Vikas Yojna*, a plan or scheme (*yojana*) by the state for the development (*vikas*) of springs (*dhara*) in Sikkim, India, from policy planning to policy implementation. The study highlights the diverse existing and emerging roles of different stakeholders, the complex relationships between them, and the power dynamics that influence the management of springsheds. The study (1) identified some new but missing actors/actor groups that were critical to managing springs; (2) showed that although state governments continue to play a dominant role, decision making is shifting to non-state and local actors; and (3) highlighted the importance of exchanging knowledge and information in implementing a policy more effectively. Understanding the characteristics of the governance network helped in drawing lessons to make the plan more sustainable and replicable, which include considering the policy in the wider context of policies for other sectors such as sanitation and hydropower development, incentivising the emerging actors, and building a stronger interdisciplinary and inclusive knowledge network. Such an integrated approach to policymaking can also be adopted to analyze governance networks related to natural resources other than water.

Keywords Multi-stakeholder governance networks · Actors and relationships · Sikkim · Power dynamics in governance · Indian Himalayan Region

Introduction

Governance of natural resources is inherently complex and difficult (Berkes et al. 2003): complex because the social (human) system and the ecological (natural) system are interconnected, and difficult because it is challenging to segregate them into discrete, self-supporting, and autonomous components (Folke et al. 2005; Liu et al. 2007). Often, the ecosystem boundaries of a governed natural resource do not match political or administrative boundaries (Bodin and Crona 2009), and the management of natural resources is affected because such system characteristics as uncertainty, non-linearity, and dynamic complexity are not fully appreciated (Berkes et al. 2003; Liu et al. 2007; Newig et al. 2010). Multiple stakeholders on different spatial and temporal scales competing for the same but limited resource can also lead to management conflicts and degradation of the resource (Bodin and Crona 2009; Fliervoet et al. 2016), and the diversity of experiences and social stratifications often create "multiple realities" and intensify the complexities associated with the governance of natural resources (Meinzen-Dick and Pradhan 2001; Reed et al. 2009; Varma and Mishra 2017). Moreover, generalizations on resource

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management are difficult because the management is context specific (Schiffer and Hauck 2010). All these aspects make the studies that address such challenges in contemporary governance mechanisms for efficient natural resource management exceptionally useful.

Until recently, the governance of natural resources revolved around a top–down command-and-control regime that aimed at securing predictable outcomes by controlling nature and harvesting its products (Holling and Meffe 1996). However, such centralized regimes were seriously flawed, because controlling a complex non-linear system invariably reduced its biological and societal diversity and made it more vulnerable (Olsson et al. 2006). Growing criticism of centralized management eventually led to a transition from "government" to "governance", with multiple stakeholders participating in the governance (Crona and Hubacek 2010; Olsson et al. 2006;). A few examples of such new forms of participatory and collaborative governance include adaptive management (Holling 1978), collaborative management (Ansell and Gash 2008), multi-level governance (Cox 2014; Janssen et al. 2006), and adaptive governance (Folke et al. 2005)—the common denominator of these new forms of governance being the focus on iterative learning, information sharing, and inclusion of perspectives of diverse stakeholders (Ansell and Gash 2008; Crona and Hubacek 2010; Hassleman 2016). However, besides recognizing plurality, the success or failure of many new sustainable governance initiatives hinges on whether explicit attention is paid to the influence of actor/stakeholder's *networks* and their *relations* (Bodin and Crona 2009; Jedd and Bixler 2015; Olsson et al. 2006). Empirical literature on how network characteristics affect and benefit governance is still in its infancy but is of growing relevance to natural resource management (Bodin and Crona 2009; Newig et al. 2010).

The present study aims to add to this emerging body of knowledge on the importance of understanding network characteristics for better governance of natural resources by focusing on a localized, relatively understudied, and shared resource, namely springsheds in the Indian Himalayan Region (further denoted as the Himalayan Region). Springsheds is the term used for the recharge area surrounding springs, which are natural discharges of groundwater from unconfined aquifers (Tambe et al. 2012). Springsheds were chosen because springs are one of the primary sources of water for mountain communities and engage a large number of stakeholders given the interconnected nature and use of water from such springs. In India, around 200 million people depend on springs for their water needs, and those living in the Himalayan Region make up the largest share of that population (NITI Aayog 2017). Recent studies have shown that the number of springs across the Himalayan Region that are drying up continues to increase because of many factors including climate change and changes in land use in the springsheds (Azhoni and Goyal 2018; Tambe et al. 2012). The deterioration of springsheds has serious implications for the sociocultural and economic life in the region and is a cause for migration and other instabilities (Azhoni and Goyal 2018). Yet, compared with the study of river and glacial systems, springsheds and their management have received little attention and literature on the topic is somewhat sparse (NITI Aayog 2017; Rasul 2014; Tambe et al. 2012). Even the few studies undertaken so far have focused primarily on hydrogeological techniques of spring rejuvenation (Tambe et al. 2012); research has mostly ignored springshed governance network structures and the challenges and opportunities that they present.

The present study uses social network analysis as a tool to understand the institutional landscape of springsheds and its influence on the public policy cycle from agenda setting and design to evaluation (Howlett and Ramesh 2003). The relevance of understanding network characteristics to identifying critical intervention points is emphasized because appropriate interventions not only increase spring water discharge and make springshed policy programs more sustainable, but also make such interventions more easily replicable elsewhere. Although the present study was exploratory and its results are context specific, the methodology can be applied to other natural resources to gain insights into managing them successfully. More specifically, the study explores the following research questions.

(i) What kind of actors are recognized by the various stakeholders engaged in the springshed program and what are their functional roles and relationships?
(ii) How did the actor networks change and evolve from policy formulation to policy implementation?
(iii) What conclusions can be drawn from the dynamic structure of the actor networks in respect of the springshed policy development process?

To answer these questions, the study developed an integrated methodology, which was empirically validated using network data from a government-implemented program for springsheds called *Dhara Vikas Yojna* (dhara is Hindi for spring, vikas is development, and yojana implies a plan, scheme, or program) in Sikkim, India.

Theoretical Background on Networks

Networks are essential for successful collaborative management and the governance of natural resources (Bodin and Crona 2009; Carlsson and Sandström 2008; Newig et al. 2010; Stein et al 2011). These networks are made up

of actors who are interconnected through socially meaningful formal or informal relationships (Cox 2014; Prell et al. 2009). The actors represent various state agencies, groups in civil society (e.g., user groups, farmers, trade associations), and firms in the private sector (Rogers 2006) that interact across geographical units, sectors, and administrative levels of governance (Stein et al. 2011). The actors participate either as formal institutions that are shaped by legal regulatory structures or as informal or customary institutions where actor relationships are formed by open voluntary agreements (Moellenkamp et al. 2010; Rahman et al. 2014). These actors help mobilize and allocate key resources and information (Bodin and Crona 2009; Jedd and Bixler 2015; Lauber et al. 2008) and their functional roles can vary from providing funds or other tangible resources, exchanging ideas and advice, and disseminating knowledge to exerting influence (e.g., through rules and regulations) (Lauber et al. 2008; Schiffer and Hauck 2010). Furthermore, networks have the potential to influence the capacity of its members to adapt to environmental change (Jedd and Bixler 2015), to build community resilience (Tompkins and Adger 2004), to foster collective action, and to promote participation and collaboration in governance (Bodin and Crona 2009; Prell et al. 2009). Given the importance of networks, new insights into innovative ways to absorb the complexities of structural networks, their influence on natural resource governance, and their use in policymaking are urgently needed (Newig et al. 2010). One such tool for studying natural resource governance is social network analysis (Bodin and Crona 2009; Crona and Hubacek 2010; Freeman 2004).

Social network analysis provides insights into relationships between actors (e.g., individuals, social groups, and institutions) (Hanneman and Riddle 2005;) and looks beyond the attributes of individual actors to examine the structural characteristics of a network (Newig et al. 2010; Prell et al. 2009). The analysis focuses on relationships, patterns of interaction in flows of resources, and positions and influence of different actors (Bodin et al. 2006; Newig et al. 2010; Stein et al. 2011) in addition to explaining the achievements of individual actors by looking at structural linkages (Schiffer and Hauck 2010) within a defined system. The analysis also helps to identify the more influential central, bridging, and coordinating actors who connect stakeholders that would have remained unconnected otherwise (Berkes 2009; Rathwell and Peterson 2012). The role of new actors is another important facet (Stein et al. 2011; Long et al 2018). These actors usually act as mediators or problem solvers and often perform functions that are often overlooked or not defined in a governance system (Long et al. 2018; Rahman et al. 2014, 2017). Such actors can reshape the relations of power and cooperation in resource governance (Long et al. 2018). Social network analysis examines such power restructuring and helps assess whether there has been a shift from state-controlled governance (i.e., a top–down "monocentric system" with a single dominant center of decision making) to a polycentric institutional arrangement with multiple, formally independent centers of decision making (Gruby and Basurto 2013; Lauber et al. 2008; Long et al. 2018; Newig et al. 2010). Further, social network analysis provides insights into interinstitutional gaps (Newig et al. 2010; Rahman et al. 2017), the possibility of collaborative action, and structural cohesion in the network (Olsson et al. 2006).

Studies across the globe have started using social network analysis to understand the governance of natural resources. Such studies include analyzing the patterns of communication between fishermen for sustainable management of coastal areas in Kenya (Crona and Bodin 2006), planning the infrastructure for water supply to cities in Switzerland (Lienert et al. 2013), understanding institutional integration in the Caribbean islands to increase their capacity to adapt to climate change (Jaja et al. 2016), and addressing institutional fragmentation in the governance of non-timber forest products (Ndenomina et al. 2018). This article uses social network analysis as a tool to analyze what different actors contribute to springshed governance in the Himalayan Region and how the pattern of interrelationships between the actors shapes the policy processes and policy outcomes.

Methods

Study Area

Sikkim was selected for the study because it was the first among the Himalayan states to have a systematic springshed management program, namely the *Dhara Vikas Yojna* (NITI Aayog 2017). Sikkim is part of the eastern Himalayas and has a geographical area of 7096 km² and a population of 610,577 (Census of India 2011). The state has an agrarian economy and depends mostly on springs for its water requirements. In recent decades, water output of these springs has been decreasing, and many have dried up because of multiple reasons including climate change (Tambe et al. 2009). The Rural Management and Development Department (RMDD) of the Government of Sikkim launched the springshed management program in 2008, which marked the beginning of springshed governance in Sikkim. The scheme sought to revive springs by employing local communities to harvest rainwater using a system of trenches and ponds in the springsheds (Tambe et al. 2009).

To derive two benefits, employment and access to water, the springshed management program was developed and linked to another scheme of the central (federal)

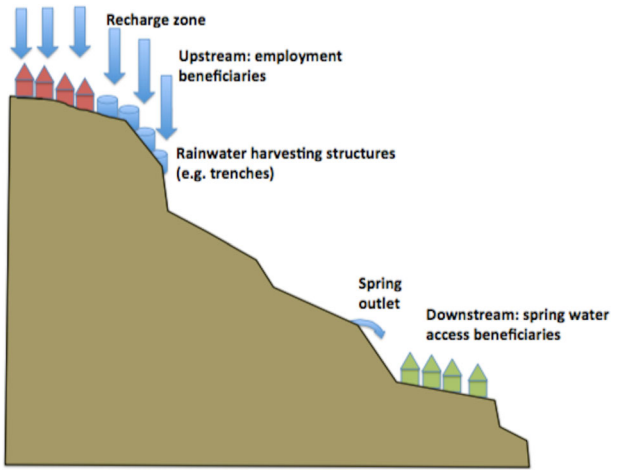


Fig. 1 Location of two groups of beneficiaries of the *Dhara Vikas Yojana*

Table 1 Characteristics of case sites

Case site (administrative unit or gram panchayat)	District	Block	Form of benefit
Deythang	West	Kaluk	Comprises both a recharge zone and a spring water outlet and therefore gains both benefits, namely employment and access to water
Turuk Ramabung	South	Melli	Has only a recharge zone and therefore derives only one benefit, namely employment
Mellidara Peiyong	South	Melli	Has only an outlet for spring water and therefore derives only one benefit, namely access to water

All the three sites were prone to drought, with steep slopes and low recharge of groundwater

government, namely the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), which guarantees 100 days of paid employment in a year to any rural household (NITI Aayog 2015), the members of which earn their wages through unskilled manual labor (www.nrega.nic.in/netnrega/home.aspx). The beneficiaries of the springshed management program, whether by way of employment or access to water, vary with the location of the recharge zone and the spring outlet (Fig. 1). Beneficiaries both upstream and downstream may be within the same village administrative unit, referred to as a gram panchayat, or in different gram panchayats but within the same larger administrative unit, namely a block (an intermediate administrative subdivision).

The study used a comparative case study approach. Three sites, each from a different gram panchayat, were selected purposefully to reflect three different benefit scenarios (Table 1). The selection helped to identify and validate the different actors and their roles from actual sites where the springshed management program was implemented.

Data Collection and Analysis

Social network analysis was used to capture the structure of governance (Fig. 2) and comprised two vital components. The first was collecting data about the nodes (actors) and links (relationships) in the network, and the second calculating network statistics that summarizes the distribution of links across the nodes (Cox 2014; Wassermann and Faust 1994).

Collecting data for network mapping involved three steps, each resulting in one or more maps of the network. Using data from different sources enabled us to gain a holistic understanding of how springsheds are governed.

The first step was to prepare the theoretical base map, or map A, based on a content analysis of a number of policy documents related to the springshed management program published by the state government. These documents helped us to understand the formal structure of the governance of springsheds as envisaged at the policy planning stage by identifying key actors and their jurisdiction, characteristics, and roles in the program. Based on the characteristics of their roles, three types of key relationships were defined (Lauber et al. 2008; Schiffer and Hauck 2010; Stein et al. 2011).

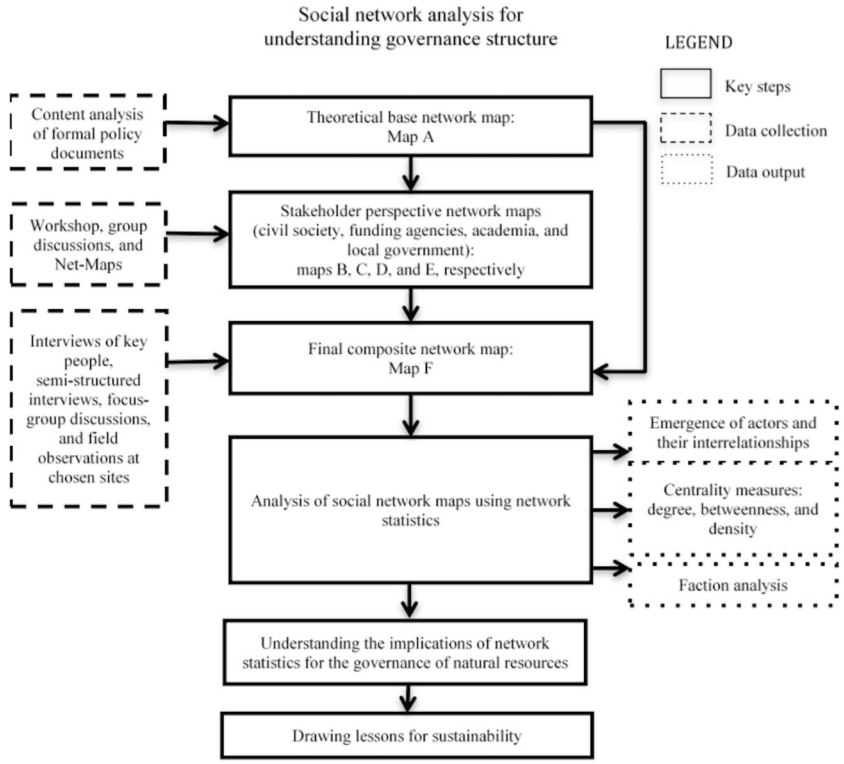
1) *Direction and command*, including government directives, technical sanctions, and approval.

2) *Information and knowledge*, including information and knowledge exchange, awareness and capacity-building programs, technical training, and collection of data on the yield of water from different springs and data related to human resources.

3) *Financial and other resources*, including financial resources and physical infrastructure.

The second step was to generate *stakeholder perspective maps*. These include civil society (map B), academia (map C), funding agencies (map D), and local government (map E) (see Fig. 3). The maps, prepared through a stakeholder workshop (which attracted 49 participants within the study region), highlighted the multiple agencies involved in the governance of springsheds. Network data were collected through a participatory tool, called Net-Map (Schiffer and Hauck 2010), which is a sketch created in a participatory setting by using color-coded sticky notes and arrows to represent, respectively, the different actors and their relationships and roles. The same three relationships mentioned in the first step were used.

The last step was to prepare a composite map (map F) (see Fig. 3) that not only captured the data from the formal policy



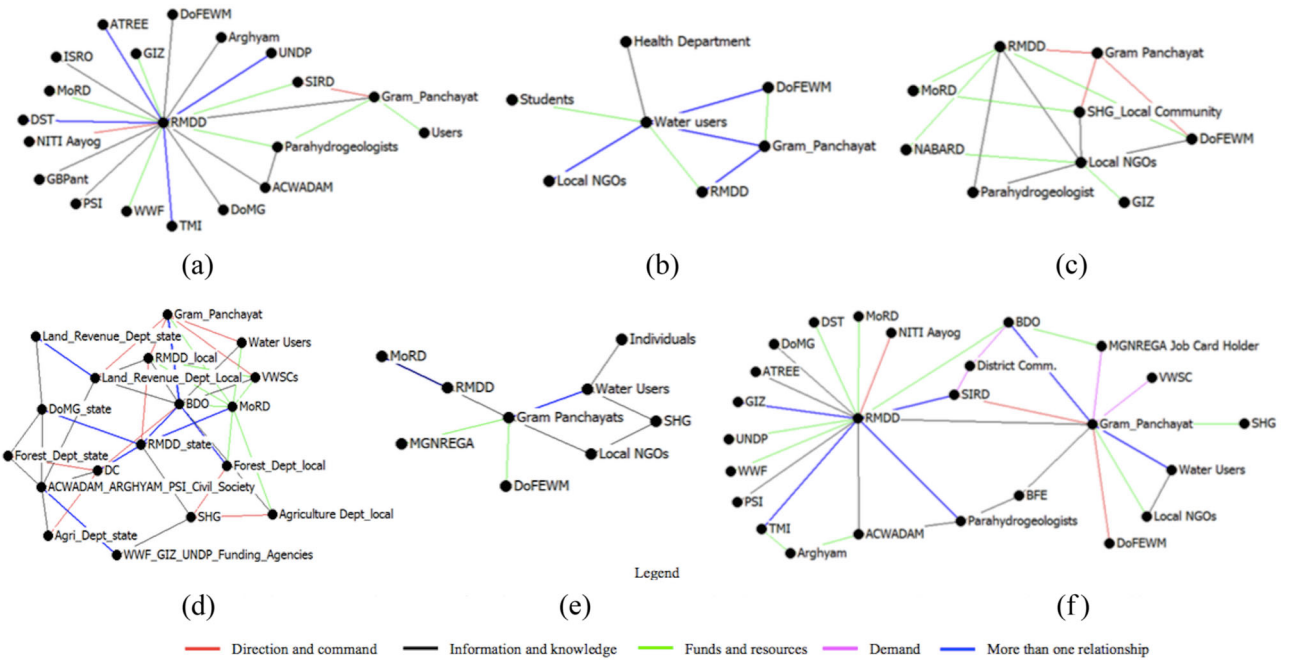


Fig. 2 Flowchart of social network analysis for understanding governance of springsheds

Fig. 3 Social network maps: Map **A**, theoretical base map; Map **B**, civil society; Map **C**, academia; Map **D**, funding agencies; Map **E**, local government; Map **F**, final composite map (for abbreviations, refer to Table 2)

documents and the stakeholder perspective maps, but also used contents from key respondent interviews and three in-depth case studies. The rationale behind this step was to locate and plug gaps, correct misdiagnoses, if any, and validate and enrich the composite map through interviews and field observations. This composite map captured the governance network that had developed after the policy was implemented. Network data were collected through a combination of 46

semi-structured interviews and 10 focus-group discussions. Participants in this step were representatives of nodal organizations, key implementers, decision makers, and beneficiaries from the case sites. Maps A to E generated earlier were also shown to the respondents for validation and enrichment. The interviewees were asked about their role in the network, the role of the organizations they were associated with, and any missing links or actors. The respondents were allowed to add or delete actors and links and even to introduce new relationships relevant to the study.

The maps were then analyzed using network statistics, which helped to assess the potential influence, power, and the degree of integration of different actors in the process of formulating and implementing a policy (Lienert et al. 2013). More specifically, we studied the most important actors and their interrelationships, degree centrality, betweenness centrality, density, and faction analysis.

Centrality measures were used for locating influential actors (Freeman 1977, 1979). Degree centrality is a measure of the number of nodes an actor is connected to. Actors with a high degree of centrality were viewed as actors that shared multiple relationships with other actors (Freeman 1979; Stein et al. 2011) and therefore had access to multiple pathways to manage resources or to distribute them through the rest of their network (Hanneman and Riddle 2005). Betweenness centrality considered an actor to be central if the actor was strategically located on the shortest path of communication between two nodes. Actors that do not lie between any pairs of nodes have zero betweenness (Hanneman and Riddle 2005). A strategic location gives an actor greater control over the other two actors (the nodes on either side) to "facilitate, block, distort or falsify" (Freeman 1977) communication between them. Density was calculated as the proportion of the total number of potential ties in the network that was actually realized. Actors in a high-density network are more in touch with other actors than those in a low-density network (Haythornwaite 1996; Wassermann and Faust 1994). Faction analysis was used for identifying subgroups comprising similarly connected actors and for understanding their working in the governance structure (Palau et al. 2004). Faction analysis also highlights weaknesses in the overall network as judged by the sizes of the subgroups. A subgroup characterized by fewer actors tend to isolate itself from the rest of the network (Hanneman and Riddle 2005).

The data were analyzed using two software packages, UCINET and NetDraw (Borgatti 2002; Borgatti et al. 2002). These packages measure network properties and convert network data into visually interpretable images (Stein et al. 2011). Qualitative data from the case studies further strengthened the analysis and helped us to understand in greater detail the significance of networks for the sustainable governance of springsheds.

Results

Networks Identified by Different Actor Groups

Network maps generated during the study (Fig. 3) show the institutional landscape of the springshed management program and its development from the formal policy design stage (map A) to the policy implementation stage (map F). Map A shows 20 actors. Some actors and links were absent in map A and became apparent only when the other maps were constructed. Thus, 11 new actors emerged in maps B to E, based on stakeholder perspectives. However, when processing data from the key respondent interviews to prepare map F after fieldwork, eight actors from maps A to E were considered redundant, and two new actors emerged. This makes a total of 25 *actors* in the composite map F (Fig. 3). Table 2 explains the role of each actor shown in Map F. The actors were classified into three categories based on their jurisdiction, namely national (central or federal level), sub-national (state, district, and block level), and local (gram panchayat level).

Functional Relationships between Actor Networks

Table 3 summarizes the actors and their interrelationship as seen in the different maps. Apart from the three predefined relationships mentioned in the methodology, a new relationship between actors, referred to as "demand" emerged in map F. Demand means a request for springshed management program for access to water or for employment under MGNREGA. This relationship connects actors such as water users, gram panchayats, block development offices, and the district committee.

Exchange of information and knowledge emerged as the most dominant relationship in all the maps (except map B). In map F, this relationship subnetwork accounted for 42.5% of the total ties and 14 actors. These numbers reflect the importance of capacity building, knowledge dissemination, technical expertise and research, data on the outputs or yields of springs and on labor, and feedback in springshed management. Therefore, a deeper analysis was carried out to identify and understand the more influential actors in this subnetwork. First, an undirected degree centrality (Fig. 4a) was calculated, which identified the RMDD and gram panchayats as the actors with the most connections and clearly pointed to the advantageous position of both actors given their potential to meet the information and knowledge needs by reaching out to alternative actors in the network (Stein et al. 2011).

The study also tried to ascertain whether the centrality of actors differed in terms of direction by measuring both the number of incoming ties (Fig. 4b) and the number of

Table 2 Role of 25 actors in map F, the final composite network map

Actor identified	Jurisdictional level	Type of institution	The role in Dhara Vikas Yojna (DVY)
Actors common in Map A (from step 1)			
National Institution for Transforming India (NITI Aayog)	National	Government	Policy planning agency that sanctioned the DVY as an approved activity under MGNREGA
Ministry of Rural Development (MoRD)	National	Government	Nodal ministry for rural development and welfare activities provides funds for MGNREGA
Rural Management and Development Department (RMDD)	Sub-national—State	Government	State nodal agency for MGNREGA and the DVY
Department of Forests, Environment and Wildlife Management (DoFEWM)	Sub-national—Local	Government	Inspects sites and provides no-objection certificates for work on forest land
World Wildlife Fund for Nature – India (WWF)	National	Research institute NGO	Initial funding and sponsorship agency; provided technical expertise on springs hydrology
People's Science Institute (PSI)	Sub-national—State	Research institute NGO	Provided initial training and shared experiences from its spring rejuvenation work in Uttarakhand
Gesellschaft für Internationale Zusammenarbeit, India (GIZ)	National	Donor funding agency	Conducted pilot studies for springshed management in Tendong, Sikkim
Department of Science, Technology and Climate Change (DoSTCC)	Sub-national—State	Government	Mapped and assessed the vulnerability of Sikkim to climate change
Department of Mines and Geology (DoMG)	Sub-national—State	Government	Provided geological maps for spring mapping
United Nations Development Program, India (UNDP)	National	Donor funding agency	Provided funds for translating the Dhara Vikas handbook (Govt. of Sikkim, 2014) into Nepali
Ashoka Trust for Research in Ecology and Environment (ATREE)	National	Research institute NGO	Provided technical assistance and is building spring-monitoring equipment; conducts research on sharing of the benefits from the DVY
Arghyam	National	Research institute NGO	Provided funding for training of para-hydrogeologists, and to The Mountain Institute for knowledge generation and capacity building
Advanced Center for Water Resources Development and Management (ACWADAM)	National	Research institute NGO	Conducts research on spring geohydrology and provides technical training to para-hydrogeologists on spring hydrology
The Mountain Institute (TMI)	Sub-national: state	Research institute NGO	Helped in GIS content development and provided technical knowledge for creating the Sikkim springs website; conducts research on sharing the benefits from the DVY and its impacts
State Institute of Rural Development (SIRD)	Sub-national: district	Government	Provided infrastructure for training of para-hydrogeologists; provides technical sanction for DVY activities by providing permissions
Gram Panchayat (GP)	Local	Government	Collects human resource (muster roll) data for MGNREGA; forwards demand requests for DVY activities to the block office; repository of monitoring data on spring discharge
Water users	Local	Civil society	Beneficiaries from access to water; responsible for creating local demand for the DYV
Para-hydrogeologists	Sub-national: state	Government	Oversee technical aspects such as identification of recharge sites and provide training and guidance to local actors such as the barefoot engineers for carrying out DVY activities

Table 2 (continued)

Actor identified	Jurisdictional level	Type of institution	The role in Dhara Vikas Yojna (DVY)
Actors common to maps B to E (from step 2)			
District Committee	Sub-national: district	Government	Approves requests for DVY activities
Block Development Office (BDO)	Sub-national: block	Government	Approves requests for DVY activities after technical approval from SIRD
Local NGOs	Local	Civil society/NGO	Awareness generation at the village level; protection of the DVY through promotion of *devithan puja* (worshiping springs as sacred entities)
Self-help groups (SHG)	Local	Civil society	Conducts voluntary drives for cleaning sources of springs and trenches
Village Water and Sanitation Committee (VWSC)	Local	Civil society	Assesses need for DYV activities and requests the gram panchayat to undertake the work related to the DVY
Actors from fieldwork (from step 3)			
Holders of job cards from MGNREGA	Local	Civil Society	Provide actual labor for the DVY under MGNREGA; beneficiaries from employment
Barefoot Engineers (BFEs)	Local	Government	BFEs are contractual employees of gram panchayats with major responsibility for small tasks related to maintenance of infrastructure related to springs; collect spring discharge data and guide such activities related to the DVY as digging trenches

outgoing ties (Fig. 4c). This analysis showed that the RMDD had an unusually high value of in-degree centrality and gram panchayats and Advanced Center for Water Resources Development and Management (ACWADAM) had a high value of out-degree centrality. These high values suggest that the RMDD carries greater prestige: many actors, including the research organizations, seek to give information directly to the RMDD to help formulate and scale up the springshed management program. Such actors are referred to as prominent actors (Hanneman and Riddle 2005). On the other hand, actors such as the gram panchayats and ACWADAM play a significant role in transmitting information and knowledge that is generated by or stored with them: such actors, who tend to share their information and are involved in generating awareness, are referred to as influential actors (Hanneman and Riddle 2005). A key takeaway from the above analysis is that both sets of actors are important for successful information and knowledge flows in springshed management.

Furthermore, betweenness centrality (Fig. 4d) was used to identify actors other than the RMDD and gram panchayats who can also control, facilitate, block, and falsify information and knowledge exchange. The para-hydrogeologists and the barefoot engineers showed high betweenness. This reflects that these actors have high probability of acting as bridging organizations who are considered crucial in resource governance for communicating information between different actors (Rathwell and Peterson 2012).

The subnetwork as a unit has a very low density (0.028), which means that information and knowledge are, most probably, not being circulated well through the network. For example, the knowledge of local customs and traditions gathered by local non-governmental organizations (NGOs) is available only to water users and likely to be lost because it is not being shared. Holders of job cards are another example: not being part of the network, they may find themselves in conflict with water users about matters related to benefit sharing because the latter do not understand how springsheds work. A denser network with more connections and a greater number of actors is important for uniform spread of knowledge.

Emergence of New Actors, Roles, and Relations

The study found how new actors, roles, and relationships emerge during policy implementation. The step-by-step method of mapping a network (as seen in map A to map F) enabled us to capture the emerging dynamics between actors within the structure of springshed governance. Some actors were not apparent in the formal policy landscape but emerged only through stakeholder experiences and

Table 3 Actors and their interrelationships forming the governance network of springsheds as identified in different maps

Map	No. of actors	No. of interrelationships	Nature of interrelationships	Most important relationship	Share (%) of most important relationship
A	20	3	Command and direction; information and knowledge; financial and other resources	Information and knowledge	48.2
B	7	3	Same as map A	Financial and other resources	57.1
C	9	3	Same as map A	Information and knowledge	44.4
D	18	3	Same as map A	Information and knowledge	38.0
E	9	3	Same as map A	Information and knowledge	57.1
F	25	4	Command and direction; information and knowledge; financial and other resources; demand	Information and knowledge	42.5

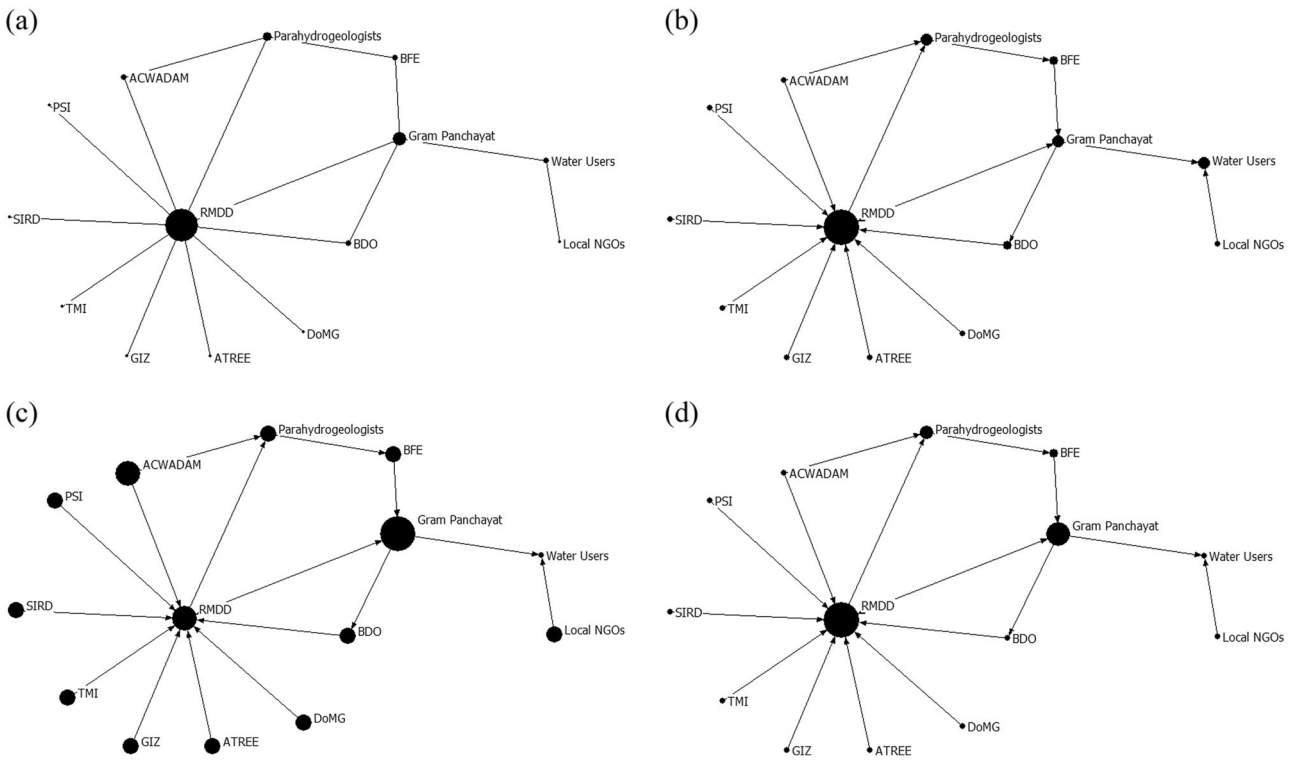


Fig. 4 Information and knowledge subnetwork of map F: **a** undirected degree centrality; **b** in-degree centrality; **c** out-degree centrality; and **d** directed betweenness centrality

engagement (Table 2), and their roles and interactions proved to be crucial for springshed governance.

Barefoot engineers as local actors illustrate the above point: these engineers were not part of the springshed management program as conceived originally but emerged later because there were not enough state government-appointed and trained individuals (locally referred to as para-hydrogeologists) available to meet the requirements of proper springshed management. Implementing the springshed program required technical expertise for activities such as hydrogeological mapping and construction of staggered trenches. This know-how was available with some actors (researchers), who passed it on to the sub-national state actors such as the staff of the RMDD or to the para-hydrogeologists. To impart the required know-how to local actors in gram panchayats, the para-hydrogeologists followed different pathways. In the initial stages, the para-hydrogeologists were directly involved in supervising the

Table 4 Combined and individual relationship-based degree centrality values in map A and map F

Map	Central actor	Normalized degree centrality				
		Combined[a]	Command and direction	Information and knowledge	Financial and other resources	Demand
A	RMDD	94.7	10.5	63.2	26.3	–
	GP	21.0	5.3	10.5	5.3	–
F	RMDD	62.5	12.5	41.7	33.3	0
	GP	41.6	12.5	16.7	12.5	16.7

For acronyms, see Table 2

[a]Using reduction approach and combined data whenever the same set of actors shared more than one kind of relationship and considered to be a single tie (Hanneman and Riddle 2005); undirected and symmetrized data

implementation. Later, as the program proved successful and became popular, they started building the capacity of local actors, namely the barefoot engineers—who were then empowered to take decisions related to the implementation of the springshed management program independently (for example, decide on the location of trenches); are paid by the gram panchayats; and are also responsible for the maintenance of minor infrastructure related to water. For the barefoot engineers, implementing the springshed management program was an additional and voluntary task. These engineers also collect data on the discharge from springs and deposit the records with the gram panchayats. Thus, the barefoot engineers have assumed a prominent role, connecting actors across the region for better management of springshed infrastructure.

Another example is the emergence of such actors as self-help groups, local NGOs, and village water and sanitation committees who do not feature in the policy documents related to the springshed management program. These actors participated voluntarily by contributing both physical labor and money to maintain trenches, organizing the planting of trees, and cleaning the area surrounding the springs. They made the locals aware of the importance of springs and of their essential features, and crafted appropriate narratives to motivate people by generating novel ideas to elicit greater participation of people in preserving the springs. The case studies show how local NGOs have prevented littering around springs by reviving the traditional practice of *devithan puja*, i.e., worshiping springs as sacred entities.

Another important local actor that emerged were holders of job cards from MGNREGA (employment beneficiaries). Maps A to E did not differentiate between the two kinds of beneficiaries, namely those who gained access to water and those who found employment, but combined them simply as users. The case studies showed that the two categories indeed comprised the same set of individuals in *Deythang*, but the two categories were more or less mutually exclusive in *Melli* and their interactions within the network were also different.

Similarly, new actors such as block development offices and district committees turned out to be important because they were required to approve various aspects of the program like budget allocations and job cards for labor under the MGNREGA and helped in identifying community needs by communicating the local labor demand for the springshed program to state-level actors.

The relationship "demand" also emerged as a result of data triangulation. Initially, representatives of the state, namely the RMDD, selected sites for the springshed management program based on formal vulnerability assessments (Government of Sikkim 2011), thereby adopting a top–down approach. However, over the last 3 years, the state has been relying increasingly on gram panchayats to come forward with requests for the springshed management program based on their own needs. This bottom–up approach has led to increased acceptance of the intervention and greater motivation to participate and provide labor beyond monetary benefits from MGNREGA.

Emergence of Polycentricity

Actors central to the governance structure of springsheds were identified based on their degree centrality. Map A identified RMDD to be the most central actor, the centrality arising from its role as the state nodal agency for the formulation and overall implementation of both springshed management program and MGNREGA. Although the RMDD (94.7% centrality) is the most influential actor in the theoretical map A, the centrality values of the actors are different in map F. Figure 3 map F, read with Table 4, clearly shows that although the RMDD continued to be the most central, its value decreased to 62.5%, probably because of the emergence of a competing actor at the local level, the gram panchayat, with a centrality value of 41.6%. The increased value of gram panchayat in map F (Table 4) points to the increasing influence of gram panchayats on multiple relationships in the governance structure.

The study captured the increasingly decentralizing decision making by highlighting the greater participation of the

Table 5 Actor groups within springshed governance structure

Actor group	Actors	Function(s)
1 (shown in black in Fig. 5)	NITI Aayog, MoRD, RMDD, DoMG, DoSTCC, WWF, GIZ, UNDP, ATREE, TMI, Arghyam, ACWADAM	Policy and knowledge generation; control policy implementation
2 (shown in blue in Fig. 5)	GP, local NGOs, SHG, VWSC, water users, DoFEMC	Local governance
3 (shown in green in Fig. 5)	SIRD, DC, BDO, holders of MGNREGA job cards	Policy implementation and linking demand
4 (shown in red in Fig. 5)	Para-hydrogeologists, BFEs	Connecting knowledge

For meanings of acronyms, see Table 2

gram panchayats, a local governance institution. Initially, gram panchayats had limited role in the policy landscape, marked by restricted interaction with a few actors. However, over time, the role of the gram panchayats and its interaction with other actors have grown following the emergence of actors such as the barefoot engineers, self-help groups, and local NGOs.

The expanded role of the gram panchayats in springshed governance encompasses local administration, which involves controlling the flow of financial and other resources (12.5%) between all local actors and submitting new demand requests (16.7%) for the springshed management program to the block- and district-level actors. In some cases, gram panchayats also play a role in making people aware of the importance of springs and of the need to protect them and also acts as a repository of information (16.7%). The information includes hydrogeological data (such as yield or discharge of springs), springshed maps generated by the barefoot engineers, data on human resources such as the number of individuals employed under the program, and a log of the labor for subsequent payments under the MGNREGA.

The case studies also showed that when gram panchayats act as information repositories, they regularly interact with government actors such as the RMDD and block development offices. The data available with gram panchayats on human resources and spring discharge help the RMDD to monitor, evaluate, and plan the actions aimed at scaling up the springshed management program in Sikkim. This expanded role of the gram panchayats from limited administration of the springshed management program to the more clearly defined and central role including the monitoring of demand and acting as an information repository has made the gram panchayat more influential in springshed governance. This, in turn, is further strengthened by other actors associated with the gram panchayat who play a key role on the ground with regard to springshed management. The overall result is the emergence of polycentricity (Ostrom 1998, 2010) in the structure of springshed governance as the springshed management program progressed from policy design to policy implementation (Howlett and Ramesh 2003).

Emergence of Actor Groups and Their Functional Positions

Faction analysis of map F revealed four groups of actors within the structure of springshed governance with unique functions from policy design to policy implementation, whereas map A showed only two groups. Table 5 lists the groups in map F, and Fig. 5 presents them in a color-coded sequence.

The four groups of actors are described below.

(1) *Group 1* (shown in black in Fig. 5) was involved in the springshed management program right from its initial stages of policy formulation, and its members initiate the directives, i.e., they set the agenda, formulate policy, and oversee and control the functioning, or implementation, of the program and are also responsible for allocating financial and other resources. Most of the actors in this group are from the top tier of governance at the national and sub-national (state) level. Some actors in group 1 also generate knowledge and help in capacity building, roles that feed into policy formulation and implementation. These actors are research-based NGOs such as the People's Science Institute (PSI), World Wide Fund for Nature—India (WWF), and ACWADAM, which were invited by the RMDD to share their experiences and to train para-hydrogeologists in technical aspects of spring rejuvenation. Such actors also conduct research on the hydrogeological regime of springs and socioeconomic impacts of the program and disseminate the findings of that research to policy actors within the group.

(2) *Group 2* (shown in blue in Fig. 5) comprises actors distributed across local levels. Most of these actors are connected to springshed management owing to their pre-existing responsibilities in local governance. They have a significant role in the local implementation of management measures. Group 2 can facilitate or hamper the implementation of the springshed management program. For example, The Department of Forests, Environment and Wildlife Management gives clearance for springshed program work in forest land in a gram panchayat, provides feedback on its progress to sub-national level actors, and plays a crucial role in initiating demand for the program.

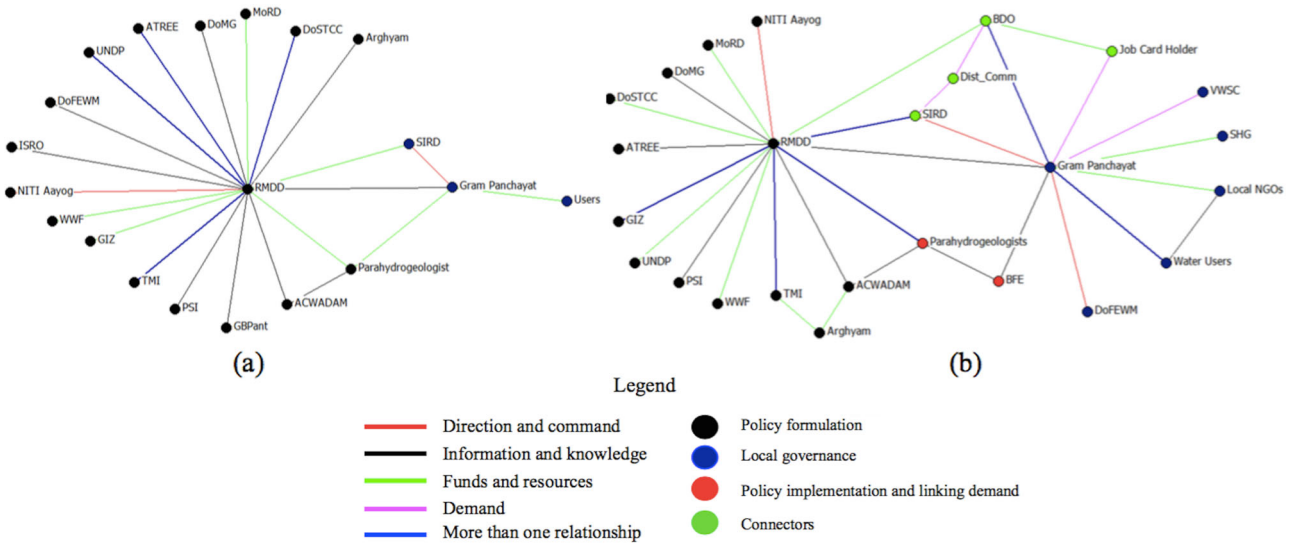


Fig. 5 Faction analysis of map A **a** and of map F **b**

(3) *Group 3* (shown in green in Fig. 5) consists mostly of actors at the district and block levels (excluding the holders of MGNREGA job cards), who perform two major tasks: they link group 1 to group 2 for approval of technical measures, remuneration, and processing demand requests for the springshed management program from water users and village water and sanitation committees.

(4) *Group 4* (shown in red in Fig. 5) comprises actors that are part of group 1 and group 2, namely parahydrogeologists employed by the RMDD and barefoot engineers employed by the gram panchayats. However, members of group 4 perform a unique function: they serve as a bridge in communicating knowledge. Parahydrogeologists acquire training on hydrogeological aspects of springs from members of group 1 (for example, ACWADAM) and pass on the know-how to members of group 2 either directly (for example, to the gram panchayats) or indirectly, through barefoot engineers. Members of group 4 also oversee and supervise local labor engaged through MGNREGA. In the absence of group 4, the relevant knowledge would only flow from group 1 (from research-based NGOs and top-level government departments) to group 3—for example, to the State Institute of Rural Development—and to group 2 (for example, the gram panchayats), making the process top–down and in turn curbing the potential for local leadership. Thus, members of group 4 serve as "connectors or bridging actors" in the springshed network and their emergence as a separate faction for communicating knowledge on technical measures affirms their high betweenness values in the information and knowledge subnetwork.

The emergence of new actors and the expansion of roles and responsibilities of all actors led to the formation of actor groups 2, 3, and 4. Faction analysis also pointed to a couple of challenges these groups may face, namely the relatively small size of some groups and the lack of formal recognition of the new actors. These challenges may make the groups more vulnerable or prompt them to form breakaway fractions. Both these challenges apply particularly to group 4, which has only two members, of which one, namely barefoot engineers, represents voluntary and informal actors, making it highly likely that group 4 will break away from the network in the future, jeopardizing the functioning of springshed management.

Discussion

The results of the study show that the springshed governance structure is dynamic and gets increasingly complex during program implementation—a facet not reflected in policy documents. Therefore, policy documents require iterative revisions to capture such changes so as to include the complex web of actors and relationships that develop over time. Such iterative revisions help in drawing attention to several critical issues not envisaged at the time of initial policy planning and in identifying opportunities for interventions to promote sustainable springshed management.

The first major concern is the limited cross-sectoral policy coherence in springshed governance. This study revealed that springshed governance does not work in isolation, and needs to be examined in the context of overall public policy, spanning many other sectors as well. This is important because stakeholder interests in alternative land-use systems and management practices may be either compatible or conflicting (Dubé et al. 2007). For example,

in the present study the policy of offering guaranteed employment (MGNREGA) affected springshed management positively. Similarly, actors from other sectors such as land use, sanitation, hydropower, and infrastructure (e.g., roads) may also influence springshed governance albeit differently owing to the interconnected nature of resources. Yet, springs as a resource are considered relevant only in formulating policies related to water and mountains, and spring development policies themselves are confined only to water supply programs (NITI Aayog 2017). Such sectoral policy paradigms are a common challenge (Rasul 2014; Sud et al. 2015) and can impede social learning (Mostert et al. 2007; Pahl-Wostl et al. 2010). Studies such as the one by Katani (2010) on spring forests in Tanzania show how a holistic overview of institutions in different sectors (for example, land, water, and forest) can help in devising better policies. Hence, the present study recommends that in the future, policy on any natural resource (including springsheds) must consider the interconnectedness of sectors and the networks of actors that form those sectors to harness synergies, reduce cross-sectoral conflicts, and achieve positive policy outcomes (Dubé et al. 2007; Rasul 2014).

The present study emphasizes that exchange of information and knowledge among actors is extremely important for the successful management of natural resources (Cash et al. 2006; Crona and Bodin 2006; Holvoet et al. 2016; Lauber et al. 2008). However, such free flow of information is being constrained by the low density of the network: a stronger and more inclusive subnetwork is essential to enhance knowledge and information transfer between stakeholders. Holvoet et al. (2016) showed that such information-sharing structures can limit multiplexity in a network, i.e., sharing multiple types of relations among two actors, including relationships that demand for action. This finding has strong negative implications for springshed sustainability because a weak information network may lead to the breakdown of a new "demand relationship", which is currently being used by local actors to mobilize springshed action and to support bottom–up initiatives. Such demand relationships are often built on a strong knowledge base and a weak base prevents actors from forging such new relations (Holvoet et. 2016; Mansuri and Rao 2013). Further, weak information flow may lead to benefits of springshed management being appropriated by the elites because only they remain connected to the network and have the relevant information to demand a springshed management program (Mansuri and Rao 2013). There is also a need to recognize local-level knowledge systems (Cash et al. 2006; Rist et al. 2016; Sud et al. 2015). A stronger network will meet the above challenges, promote mutual understanding between stakeholders, and will also prevent possible bottlenecks and conflicts that threaten equitable distribution of, or access to, resources (Holvoet et al. 2016; Rist et al. 2016). One way to build such networks is to hold short-duration capacity-building programs, multi-stakeholder experience-sharing workshops, and exposure visits.

The study also identified the importance of new local and non-state actors. These actors were missed when the policy was conceptualized and formulated, but emerged during policy implementation to perform a range of important functions including functions that, traditionally, had not been expected of them. Emergence of such actors has also been reported in other studies (Krishna 2011; Rahman et al. 2014, 2017; Stein et al. 2011). Some of these studies showed that incorporating new actors may not always benefit resource governance. Voluntary new actors may act as opportunists and become a barrier to communication between formal and informal institutions, create mistrust, and jeopardize equitable distribution of resources (Krishna 2011; Rahman et al. 2014). However, we found new actors to be assets, and no actor turned out to be an opportunist. Some actors may leave the network because their role is voluntary. Owing to such challenges, it is necessary not only to identify new and missing actors but also to recognize their roles and offer them suitable incentives to ensure their positive involvement in resource governance. One such mechanism is to incorporate actors from informal institutions into a new formal institution (Rahman et al. 2014). For springsheds, we found that financial incentives and social commendations encouraged informal actors to continue playing their role. However, such incentives also carry multiple risks (Putzel et al. 2015), and policymakers need adequate bottom–up studies supported by researchers and practitioners to operationalize any incentives.

Another important finding from the study is that local authorities play a major role in governance during project implementation alongside institutions at national or state level. The present study has shown how increased connectedness of the gram panchayats with new actors has led to expansion of their role and, eventually, to the development of polycentricity (Ostrom 1998, 2010). This strengthens the contention that although a governance structure is monocentric or hierarchical at the beginning of policy cycle, different actors—both informal and formal—often get connected to exchange knowledge, share power, and work together toward a common interest, resulting in network governance during implementation. However, although there is a clear and positive trend of a shift in decision-making power from state to local authorities, the state government continues to dominate, because the participation of local and non-state actors in policy formulation is still found to be lacking in springshed governance. That lack implies that springshed governance is yet to become fully polycentric (Gruby and Basurto 2013; Young 2006). The lack of representation of local actors during policy formulation is a major gap and can lead to the neglect of relevant local issues by state actors and

constrain policy implementation involving wider collective actions (Gruby and Basurto 2013; Klijn and Koppenjan 2000). This observation is consistent with the findings from a few case studies, such as those by Katani (2010), Long et al. (2018) and Ndenomina et al. (2018). On the other hand, some researchers (for example, Fliervoet et al. 2016) suggest that a dominant formal bureaucracy can help in hierarchical collaboration, for example, by selectively empowering weaker actors (assuming that public actors act in the interest of all members of society). Hence, it becomes clear that increasing stakeholder engagement during agenda setting (Katani 2010; Ndenomina et al. 2018) will help in better springshed management and can be achieved by creating a common platform for collaborative discussion (Klijn and Koppenjan 2000). Such platforms can be created and regulated by formal public actors—because they often possess adequate resources—with inputs from such actors as researchers and local NGOs (Fliervoet et al. 2016; Ndenomina et al. 2018).

Finally, our analysis found that the springshed governance landscape comprises four groups of actors, each with its specialized functions. The study emphasized the importance of recognizing not only the role of the dominant larger groups, namely group 1 and group 2, who play a key role in decision making related to policy formulation and local governance respectively, but also of other smaller and newer actor groups, namely group 3 and group 4, who have started acting as connectors in springshed governance and who link demand for services and knowledge respectively. These smaller groups support formal state-level institutions (e.g., the RMDD) by acting as go-betweens for exchange of information. In the absence of such mediating agencies, the flow of resources between actors operating under formal and informal institutions may stop or become less efficient, leading to a structural hole, an interinstitutional gap (Cash et al. 2006; Rahman et al. 2017). Already the signs of such gaps between dominant groups in knowledge exchange (such as data on discharges from springs) are becoming visible with the decrease in the number of experienced para-hydrogeologists (Azhoni and Goyal 2018). Such cross-scalar challenges are difficult to manage. However, recognizing and mainstreaming these new functional positions that did not feature in policy documents may prove beneficial in sustaining springshed governance.

Conclusion

Social network analysis proved to be an effective tool for gaining systematic insights into the emergence of actors that make up a governance structure, the evolution of their roles and relationships within a policy cycle, and their influence on the outcomes of a policy. Using springsheds in the Indian Himalayan Region as a case, the study showed that governance of natural resources is dynamic and becomes increasingly complex as the policy cycle continues because of greater participation of many new stakeholders, especially local and informal actors, in policy implementation. Further, the analysis revealed that involvement of such actors and their relations can change the power dynamics between actors from different spatial jurisdictions and can be critical to the decentralization of the governance process. The network structure also highlighted the emergence of actor groups that have distinctive functions and are essential for bridging inter-institutional gaps and for sustainable springshed management. Beside shedding light on the roles and responsibilities of both pre-existing and emerging stakeholders and their power dynamics, the article highlights the importance of specific relationships such as those that promote exchange of information and knowledge among actors for sustainable management of natural resources.

Given that the governance of natural resources is complex because of multiple stakeholders on varying scales, any shift toward more sustainable and equitable management of resources will need to focus on the networks of actors and the dynamics of such networks across all stages of the policy process. The present study used social network analysis to understand some challenges and opportunities related to effective governance of springsheds and, on the basis of that analysis, suggests that the emergence of new or unforeseen actors and their interrelationships be recognized and leveraged, along with new roles among existing actors through time and space. The study also recommends iterative assessment of networks throughout the policy cycle to create a more inclusive stakeholder network and a common platform for sharing information and knowledge. Attention to these dynamic aspects of a governance structure will help achieve and sustain positive policy outcomes and scaling up interventions.

Acknowledgements We thank Dr. Ghanashyam Sharma for his valuable suggestions. We also thank all the respondents who participated in the workshop, field discussions, and interviews. We also thank two anonymous reviewers for their constructive comments to an earlier draft of this paper. The study was conducted with funding support from the Himalayan Adaptation, Water and Resilience (HI-AWARE) Research Consortium. The views and opinions in the paper are solely those of the authors.

Compliance with ethical standards

Conflict of Interest The authors declare that they have no conflict of interest.

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