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The network analysis of organizations in watershed management toward sustainability in Northern Iran

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Introduction: The integrated water resource management is considered for development planning and water and soil resources management with an emphasis on the socio-economic features of the region for sustainability. The main purpose of study was to identify the organizations involved in the watershed management of Chehelchay of Golestan province in Iran, as well as analyzing the types of communications and interactions between organizations in terms of intensity and type.

Methods: Three networks of information exchange, coordination and participation were studied due to network analysis. Thus, the related organizations involved in participatory and comprehensive management of Chehelchay watershed (30 organizations) were introduced during the trips of the research team to the site and using special questionnaire. Then, the other specialized questionnaires were collected from the informed panels of each organization to provide the required data in the network analysis. A total of 84 specialists were interviewed. About half of the respondents (42 individuals) had graduate education and their average work experience was about 15 years. One third of the respondents (28 individuals) were women. The data analysis process was performed with UCINET6.631 and NetDraw.

Results and Discussion: The results indicated that the density index in information exchange (31.5%), coordination (27.5%) and participation (10%) networks were less than average. In the participation network, the values of the density index are very low and coherence is the same among the networks (information exchange, coordination, and participation). The results of reciprocity index among the organizational actors in the networks of information exchange (31.10%), coordination (33.52%) and participation (10.13%) were also less than average. Therefore, identifying the key actors with high social power in the network of local natural resources is a requirement of watershed participatory management plan. The runtime and cost of implementing natural resource projects can be significantly decreased by understanding and deploying these organizations and individuals. Social power and comprehensive participatory management is generally the key tools for building trust between local natural resource users. A systematic shift is also required from governmental management toward governance in order to achieve sustainable natural resource and watershed management.

KEYWORDS

network analysis, watershed management, information exchange, coordination, participation, Iran

1 Introduction

Natural resources are considered an inseparable component of human life. The scope of activity of ecosystems are separated based on the boundaries that humans have established due to political and social considerations. Thus, the scope of natural resource management has been defined due to the political divisions of countries, states, and provinces. This has led to the formation of numerous organizations and stakeholders with different interests competing with each other for the exploitation of natural resources services. Several strategies have been raised on the appropriate and sustainable use of global natural resources. In this regard, watershed management has been regarded as a comprehensive and appropriate method for the sustainable management of natural and human resources in watersheds. In recent studies, experts emphasized the model of "governance" of natural resources instead of the model of "governmental management" (Duit and Galaz, 2008; Salajegheh et al., 2020). The governmental management model largely relies on specialized knowledge and lacks the conditions to integrate social issues with biophysical conditions through cooperation, coordination, real participation, negotiation, and conflict resolution between different stakeholders. While governance as a wide system includes formal and informal organizations, each of them has its own structure, strategy, and resources, and they also play a significant role in the process of resources management as well as common-goals achievement (Armitage et al., 2007). Therefore, in the governance model of natural resources, social issues are facilitated through flexible and compatible mechanisms and cooperation between organizations (Carlsson and Berkes, 2005). In this regard, the participatory management approach based on compatibility emphasizes the social aspects of the management process (Armitage et al., 2007).

In governance model, institutions that are responsible for the management of socio-ecological systems change behaviors to consider all stakeholders based on a systematic process due to the pattern of participation and learning (Armitage et al., 2008). This model emphasizes a fundamental concept involving the need for coordination, participation, and learning among researchers, organizations, and resource managers (Dougill et al., 2006; Reed et al., 2009). The main point is the identification of organizations and stakeholders that each have their own management area, and that they are also related to each other in the resource governance process. The process of selecting and organizing the stakeholders is considered as one of the main pillars of Adaptive Co-Management (ACM) (Armitage et al., 2007). Replacing the classical managerial system with the governance model instead has drawn the attention of many scholars toward the study and analysis of natural resources governance (Ostrom, 2005; Salajegheh et al., 2020). Studies in this regard have led to the emergence and growth of some principles and applied models for the development and improvement of common-pool resource governance methods, many of which, especially the coordination, participation, and learning resulting from them, are basically related to social interactions (Plummer et al., 2012).

The contradictory view on watershed resource management is one of the biggest reasons for failure in watershed management in Iran. The multiplicity of organizational stakeholders with changing policies, approaches, priorities, capacities, and interests, and the lack of a comprehensive system to identify their role and structural relationships in the watershed management network are the most significant challenges faced by integrated watershed management in Iran. In participatory resource management, identifying key stakeholders is significant in terms of which stakeholders are more influential on the participatory management of natural resources based on their relationships with other people in the network (Fatemi et al., 2021). In this regard, social network analysis would be an appropriate method to use.

1.1 Social network analysis and watershed management

The concept and theory of social networks was first introduced by Alfred Radcliffe-Brown in 1940 and was used by Barnes in the 1950s (Korom, 2015). The main approaches of network analysis are divided into three main groups: the metaphorical approach, descriptive approach, and structural explicit approach (Folke et al., 2005; Hahn et al., 2006). In the metaphorical approach, social networks are often considered as a metaphor. The general idea of this approach is that each of the actors in the social area that form the network are either related to each other and benefit from this relationship to achieve different goals, or they are not related to some people and are more self-reliant. Overall, this approach includes a series of applied studies in which social networks have been considered as a research tool in the governance of natural resources. But it provides little information about the real structure and patterns of social networks. Thus, this approach lacks the analytical and explanatory capabilities of the social network, and it is difficult for the researcher to investigate the effect of a specific factor in social networks through analytical processes such as participation and coordination (Fabricius et al., 2007).

The descriptive approach goes beyond the metaphorical approach; specific features of social networks such as horizontal and vertical networks, links, communication bridges, and network density are studied in this approach (Pretty and Ward, 2001). But this approach lacks a methodological strategy for identifying and differentiating aspects of social network structures and provides little ability to increase our understanding of various issues of social networks in relation to natural resources. The structural approach has transformed the researcher's perception towards the concept of network structures and their function by introducing computational and quantitative aspects in the process of network analysis (Hahn et al., 2006). This approach includes a set of studies that examines social networks through applying systematic methods of data collection related to network relationships, methodology, and calculation-based modeling. The final goal of this approach is to explain the relationship between official definitions through quantitative and calculable features of the structure of social

networks, and to present the results obtained from the analysis of this relationship in the governance of natural resources (Folke et al., 2005). The structural approach was used in this current study.

Social networks consist of a set of relationships and nodes, that is, the various types of stakeholders and the relationships between these stakeholders (nodes). In general, a social network can be considered as a graph of nodes and lines. Nodes in the network represent the actors and lines between nodes indicate the relationships between actors. Network analysis provides an empirical basis or an understanding of the flow of information and influence in governance networks to identify key organizations (Vignola et al., 2013). The main research on social networks seeks to understand how individual patterns of social relationships affect behavior (Ford et al., 2011). Social network analysis allows research into relationships beyond purely physical relationships and very significant relationships, and can provide very useful results which help improve social processes (Molano and Polo, 2015). Network analysis focuses on the relationship between actors, not on the actors themselves and their characteristics. Network analysis criteria can indicate the relationships between organizations, including which ones have the most active members of a network or those whose connections are interrupted by network members (Pedroza et al., 2016).

From a theoretical point of view, social network analysis is based on network theory and graph theory. Network theory is a very general term for evaluating relationships (Celik and Corbacioglu, 2016). Using social network analysis techniques, researchers evaluate social networks with a focus on relationships between individuals and organizations, and social network analysis has been widely used to help improve the efficiency and effectiveness of decision-making processes. In addition, it may identify the groups of people that have a central role, or separate groups or individuals. Further, it can identify opportunities to improve the flow of information and knowledge, improve the efficiency of formal communication channels, and increase the importance of informal networks (Bae et al., 2015). In social network analysis, more emphasis is placed on the type, quantity, and quality of communications and interactions instead of on the underlying variables. Indeed, matrices include the actors involved in interaction as well as the direction and frequency of interaction between them (Celik and Corbacioglu, 2016). An important point about the analysis of organizational networks is that the components of different organizations are not in direct contact with each other and their connections are *via* complex, extensive, and multiple relationships. Here, the concept of a network becomes necessary for the analysis of organizational relationships.

In many cases, Social Network Analysis (SNA) is used as a tool to determine influential actors in a collaborative process (Narayan et al., 2020). SNA makes it possible to study the interactions between activists, organizations, and other individuals who are involved in the process of natural resource management and governance. It is seen as a valuable method in management and governance studies. Focusing on the system's relationships and not its elements is the main emphasis of this method. In other words, it examines all the system's connections and provides a comprehensive understanding of its social structures and actions through discovering the relationships. This strategy is the main basis of the social communication hypotheses (Emirbayer and Goodwin, 1994; Freeman, 2004). This method can identify different social factors in the process of common-pool resource governance and can be used to determine these factors in the success or failure of resource management as well (Bodin et al., 2006; Bodin and Crona, 2009). For instance, SNA will determine what is the pattern of relations between activists and organizations in order to avoid the tragedy of common resources and to establish their self-imposed systems to use these resources in a regulated and sustainable manner (Prell et al., 2009). Obtaining such information is very valuable for external institutions that have the mission of facilitating the process of developing communication patterns between actors (Schneider et al., 2003; Ernstson et al., 2010). Therefore, SNA can be used as an efficient tool to analyze the process of information flow and knowledge exchange in the network of stakeholders and organizations; it can be used to create a successful system for the development and distribution of natural resources knowledge (Dempwolf and Lyles, 2012). In fact, mutual relationships between organizations in social networks play a much more important role than the development of official organizations to define and observe the rules of natural resource exploitation (Scholz and Wang, 2006).

There are several publications that have used SNA to study different aspects of environmental, natural resources, and watershed management and governance. For instance, Raum (2018) argued that appropriate models for ecosystem services need to identify different actors. The study showed that ecosystem governance and management would be effective and sustainable if various stakeholders and ecosystem services and their abilities are analyzed using the SNA method. In a similar study by Giurca and Metz (2018), SNA was used to identify some of the main organizations involved in Germany's wood-based bio-economy innovation system and their relationship to each other. The figures indicated high density but this was only due to the information exchange of the actors. Based on the results, although the connection between organizations was weak, the level of trust was high due to their cooperation. Application of SNA was also used in the study by Ghorbani and Azadi (2021) to analyze trust and collaboration networks in rangeland co-management. It found low levels of trust and collaboration between different stakeholders including rangeland users and the experts and managers of governmental and non-governmental institutions. This caused severe challenges in the governance of natural resources.

Narayan et al. (2020) studied the governance of decentralized watershed treatment in four cities of India. According to the complexity of the different groups of stakeholders involved in the governance of Water, Sanitation and Hygiene (WASH) and the diversity of their interests, SNA method was used. The results revealed the key differences between mega- and secondary cities in terms of institutions, community engagement, and overall sanitation, including aspects of decentralized wastewater treatment plants, based on the city types. Another study by Nabiafjadi et al. (2021) analyzed the knowledge and information exchange networks among governmental organizations and NGOs that contributed to water governance in the Zayandeh-rud basin of Iran. The study showed that the collaboration of the institutions was necessary to implement better strategies in water management. It also indicated that high participation of the mentioned

organizations as well as identifying power relations and densities in different processes of water governance could be used in other countries of the Middle East. The role of various actors and their social capital in groundwater management was analyzed using SNA in the study by Rahimi-Feyzabad et al. (2022). It revealed that the social capital of these organizations was low. In fact, the heterogeneous nature and contrasting strategies of these organizations led to the poor collaboration.

Reviewing the most recent year of SNA study publications, this method was used in different research areas as well: Joyez and Laffineur (2022) studied the occupation space, network structure, centrality, and the potential of labor mobility in the French labor market; Flemming et al. (2022) used the SNA method to identify networks of physicians responsible for the care of specific patient populations; Blanken et al. (2023) studied intersectoral collaboration at a decentralized level, and information flows in child welfare and healthcare networks; and Arnold et al. (2022) studied information exchange networks regarding chronic diseases in primary care practices in Germany.

The network analysis method is used for identifying the main stakeholders and actors in the community (Bodin and Prell, 2012). The appropriate understanding of the position and capacity of the main actors and stakeholders can lead to their appropriate organization in collaborative management programs (Ghorbani and Azadi, 2021). The current study aims to identify the organizations involved in the watershed management of Chehelchay in Golestan province, Iran, and analyze the communications and interactions between the organizations in terms of intensity and type. The research objectives are as follows:

- Identifying the various organizations active in Gorganrood watershed management
- Undertaking network analysis at the organizational level and studying the various relationships of relevant organizations in the studied area
- Providing applied suggestions to improve and enhance the interactions of various organizational stakeholders to implement the comprehensive and participatory management of the watershed.

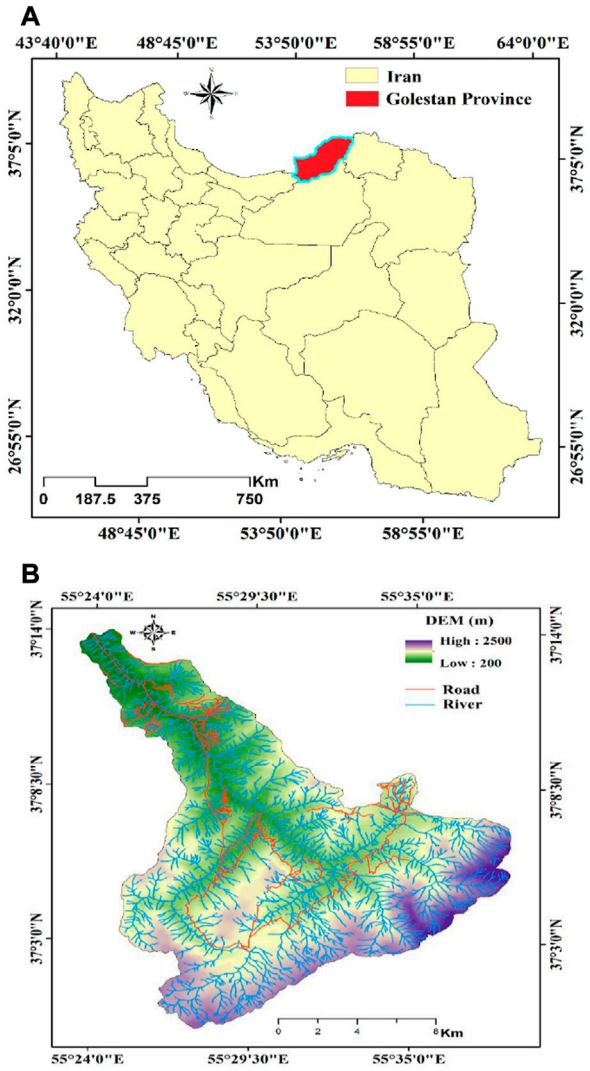

FIGURE 1
Geographical location of the study area **(A)** Golestan province on map of Iran **(B)** Chehelchay watershed of Golestan province.

2 Research method

2.1 Research area

Golestan province (Figure 1A) has six sub-watersheds including the Voshmgir watershed dam with 8,100,000,000 square meters (m^2), Western Gorganrood watershed with 3,500,000,000 m^2, Atrak watershed with 8,000,000,000 m^2, Qareh Sou watershed with 1,650,000,000 m^2, Gorgan bay watershed with 400,000,000 m^2, and Nekarood watershed with 1,000,000,000 m^2. The highest level of altitude of the province and consequently the maximum water available in the province comes from the Gorganrood watershed which is considered one of the most important rivers in Golestan province, flowing through all plains of Gorgan and dividing it into two parts. The main bed direction is from northeast to southwest, is 350,000 m long, and originates from the heights of Golestan forest. Chehelchay watershed is one of the mountainous regions of Iran with an area of about 61,777 acres located between 55° 23 and 55° 38 east longitudes and 36° 59 and 37° 13 north latitudes (Figure 1B). This watershed is located in Minoudasht in terms of political divisions and is one of the largest sub-watersheds of Gorganrood.

2.2 Sampling and data analysis

Network analysis is based on the common social science method of using different techniques, such as interviews and questionnaires, to collect the required data (Butts, 2008; Bodin and Prell, 2012). In this study, the social network of related organizations was analyzed. Thus, the related organizations involved in the participatory and comprehensive management of the Chehelchay watershed (30 organizations) were introduced during the trips by the research team to the site and using specialized questionnaires. Based on purposeful sampling, key informants were selected

TABLE 1 Introduction of social network analysis indices.

Index	Definition
Power	The concept of power is reduced or increased based on the status, position, and communication of each individual or organization within the network and due to the constraints or opportunities created for them Brandes and Erlebach (2005). The fewer limitations of an individual or organization, the more their opportunities will be, and as a result they will achieve a more favorable position Bae et al. (2015). Thus, they will make more exchanges with others, and will have more impact.
Grouping	Grouping the actors of a network allows understanding of how an agent or organization behaves within a group, as well as the overall behavior of the network Leahy and Anderson (2008). Also, the identification of weak and strong sections within a network is provided by examining the number and severity of communications between and within the groups Fatemi et al. (2021).
Centrality	Centrality is a broad concept used to identify the most important actors in the network. It indicates the degree to which an actor is embedded in the network Freeman (1979), Narayan et al. (2020), Joyez and Laffineur (2022)
Degree centrality	The value of degree centrality of any point or organization is obtained only by counting the number of neighbors or adjacent organizations Herzog et al. (2014). In its analysis, the greater the degree centrality of a person or organization, the more communications and networks it has, and it is more powerful and influential Zhang and Lou (2017). In-degree centrality measures the number of nodes that an actor receives, and the out-degree centrality measures the number of nodes leaving an actor Saqr and Alamro (2019)
Closeness centrality	It represents how fast an actor can access others in the network. In fact, it is considered as the mean of all geodesic distances between mentioned actor and other actors in the network Zhang and Lou (2017). Proximity centrality is an index for measuring the ease of access at the node to the rest of the nodes in the network Gandasari et al. (2022).
Between centrality	In this type of centrality, the organization's position in the network, as well as its path to other organizations, is considered. What matters is finding the shortest path between organizations. The actors with high between centrality can influence the flow of resources among other actors Zhang and Lou (2017). These organizations are the intermediary points that the communication paths pass through. The importance of identifying and analyzing such points is their strength in limiting or increasing communication Saqr and Alamro (2019)
Eigenvector centrality	This focuses on finding central actors that are least distant from others Gan et al. (2018)
Network density	Density in the information network means the ratio of all available links or information nodes in the network to all possible links or the most nodes; high network densities represent a high degree of consistency among individuals Narayan et al. (2020), Rezaei et al. (2015).
Reciprocity of links in the network	In order to determine the stability of the network of relationships and the degree of reciprocity of the links of trust and participation, the reciprocity of links in the network is used Karimi Gougheri et al. (2018b). The higher the level of this index in the network of relationships is, the higher the level of constructive interaction between the people in the network, and the stability of the network of relationships is ensured Fatemi et al. (2021).
Transitivity of links in the network	This index is derived from the sharing of links between three individuals, one of which is the bridge between two other people Borgatti et al. (2013)
The shortest distance between two actors **(mean Geodesic distance)**	This index shows the shortest path between two pairs of actors based on trust and participation links. The higher the rate of this index, the more the speed of circulation, distribution of trust, and the links of participation among individuals and unity in society Bae et al. (2015).
E-I[1] Index	This index displays the links outside the group to the links inside the group. Individuals with EI-positive have more links outside the group; EI-negative individuals have more links inside the group, and those with zero EI have equal inter-group and intra-group links Fatemi et al. (2021).
Network size	This indicates the total number of links in the network; the larger the network size, the greater the density of the network Mohammadi Kangarani et al. (2011).
Isolates	The actors who have nothing to do with other actors in the network Herzog et al. (2014), Fatemi et al. (2021).
Core/periphery	This index demonstrates which actors are located in the center and which ones are located around the network. Using this indicator, all members are divided into two groups of centers and surroundings Herzog et al. (2014); Gan et al. (2018). The central cluster has a lot of connections and therefore the network density is low Narayan et al. (2020).

among the experts, managers, and authorities of these organizations in order to collect the required data in the network analysis. In these panels, a total of 84 specialists (three individuals from each organization) were interviewed. Then, the data were entered into Excel and UCINET6.631 software in the form of a matrix, and data processing and analysis were performed. This data processing was conducted using the concepts which are the basis of all of the mathematical algorithms (Klenk et al., 2009; Herzog et al., 2014). The most important of these concepts is centrality, power, and grouping (Narayan et al., 2020; Fatemi et al., 2021). Graph theory and NetDraw software were used to plot the data (Scott, 2012). In this research, a number of social network analysis measures were analyzed

to assess the different network criteria between individuals, between organizations, and between individuals and organizations (Table 1).

2.3 Research steps

In order to conduct the present study, eight steps were performed to examine the existing interaction and communication patterns among the actors using the social network analysis technique (Brandes and Erlebach, 2005; Vignola et al., 2013; Bae et al., 2015; Fatemi et al., 2021).

Step 1. Determining the type of analysis
Step 2. Determining the relationships within the network using the theoretical measurement tools
Step 3. Collecting the data related to the network
Step 4. Measuring the relationships
Step 5. Entering the characteristics of actors in the analysis
Step 6. Analyzing the data related to the network
Step 7. Creating descriptive indices for social structures
Step 8. Providing data for each network

In the present study, various social networks were studied and analyzed at organizational and social levels:

2.3.1 Information Exchange

Organizations communicate with other organizations when information is required regarding other organizations' programs or *vice versa*. In other words, the organizations collaborate with each other only for information sharing, and they work together only when the opportunity arises (Giurca and Metz, 2018; Rocker et al., 2022). For example, the Regional Water Company provides some information about unauthorized wells for the Organization of Agriculture Jihad or Meteorological Organizations provide information regarding weather forecast for Department of Environment.

2.3.2 Coordination

In order to prevent duplication, organizations coordinate with other organizations. Indeed, the organizations inform each other of their plans and schedules to prevent attending repeated programs (Mohammadfam et al., 2015; Karimi Gougheri et al., 2018a). For example, the Agriculture and Natural Resources Engineering Organization and Golestan University share their educational schedules of the current year so that parallel educational classes and workshops are not held for different groups of agricultural clients.

2.3.3 Participation

As a specialized team to achieve a common goal, the organizations participate with other organizations. This means that different organizations have mutual collaboration with each other from the process of decision-makings to the implementation phase (Ghorbani and Azadi, 2021; Flemming et al., 2022). Participation is considered as a specialized concept in social science, indicating the highest level of communication between individuals, organizations, and societies. For instance, the national/regional strategic plan is defined to be completed by Golestan University, the Organization of Agriculture Jihad, Department of Natural Resources and Watershed Management, and the Department of Environment in a participatory manner.

3 Results

The results of first questionnaire, which determine and introduce the active organizations in the watershed management of the Chehelchay region, have been provided in Table 2. Based on field studies and observations, 30 organizations which have been active in the watershed network were identified. Their full names as well as their abbreviations are presented in Table 2.

3.1 Description of the sample

All of the respondents had an academic education, except for two individuals finishing their high school. Nearly half (54%) of the samples had a master's degree, and bachelor's degree and Ph.D. were the subsequent most frequent education levels achieved, respectively. Based on the findings, 50% of respondents were in their second decade of working. After that, the individuals with more working experience with more than 20 years of work experience constituted 28% of the sample, and the remaining 21% included young workers with less than 10 years of experience (Table 3). One third of respondents (28 individuals) were female experts and two thirds were male experts.

The age range of the respondents was 28 years, with a minimum and maximum age of between 26 and 54 years old. The average age of respondents was about 41 years and the highest recurrence age among the sample was 40 years. In terms of the degree of education, the minimum and maximum number of years of study was between 12 and 23 years to give a range of 11 years. The average study years of the studied sample was 18 years (to master's degree). The results included a diverse range of occupational backgrounds, meaning that both people with 30 years of work experience and on the edge of retiring and freshly recruited staff with 1-years' experience could be observed. The average years of employment was 15 years and a large number of people in the sample had an occupational history of 20 years.

3.2 SNA of organizations

3.2.1 Information exchange network

The size of the information exchange network is 274 links from the expected 870 total links. The calculated density index in the information exchange network is 31.5%, which is lower than the average, indicating the low level of institutional coherence based on this link (network) in the organizations affiliated with watershed management (Table 4). In other words, achieving and sharing information on watershed management in organizations is not easy and has many problems. The network centralization index based on the input and output links in the information exchange network is 35.2% and 45.9%, respectively. In addition, the percentages of 31.1% for link reciprocity and 46.2% for link

TABLE 2 Full names and abbreviations of the organizations involved in the Chehelchay basin.

Abbreviation	Organization's full name
OAJ	Organization of Agriculture Jihad
DENV	Department of Environment
NRWM	Department of Natural Resources and Watershed Management
RWC	Regional Water Company
ANRREC	Agriculture and Natural Resources Research and Education Center
GH	Government House
ANREO	Agriculture and Natural Resources Engineering Organization
MO	Meteorological Organization
DEDU	Department of Education
PVO	Provincial Veterinary Office
RWWC	Rural Water and Wastewater Company
CLSW	Department of Cooperative, Labor, and Social Welfare
NAO	Nomadic Affairs Organization
SFDA	Support Fund Development in Agriculture
UPCC	Union Production Cooperative Companies
UNAC	Union of Nomadic Agriculture Cooperative
ASSC	Agriculture Support Services Company
AIF	Agriculture Insurance Fund
SIFVN	Social Insurance Fund for Farmers, Villagers, and Nomads
CCIMA	Chamber of Commerce, Industries, Mines, and Agriculture
AEA	Agricultural Experts' Association
AGS	Agricultural Guild System
ORC	Organization of Rural Cooperative
WO	Welfare Organization
CHHTA	Cultural Heritage, Handicrafts, and Tourism Administration
GU	Golestan University
ANRBO	Agricultural and Natural Resources Engineering Basij Organization
BO	Broadcasting
IKRF	Imam Khomeini Relief Foundation
HA	Hilal Ahmar

transitivity indicate low and average stability of the information exchange network among the organizations involved in watershed management, respectively.

In order to investigate the role of different organizations in the studied networks, the values of in-degree and out-degree centralities were compared. Based on these indices, the amount of information received or provided in the information exchange network was determined. As shown in Figure 2A, the findings indicated that Iran Broadcasting, the Department of Natural Resources and Watershed Management (NRWM), the Government House, the Regional Water Company (RWC), the Department of Environment (DENV), and the Organization of Agriculture Jihad (OAJ)—with out-degree centrality levels of 75.9%, 72.4%, 58.6%, 58.6%, 55.2%, and 51.7%, respectively—had a higher social permeability in the information exchange network for watershed management based on

TABLE 3 Demographic characteristics of respondents in the studied organizations.

Variable	Mean	SD	Min	Max	Mode	Range
Age	41.12	5.920	26	54	40	28
Educational level	18.07	2.592	12	23	18	11
Background	14.76	6.726	1	30	20	29

TABLE 4 Indicators measured of the studied networks.

Network	Density (%)	Centrality (%)	Network centrality based on input links (%)	Network centrality based on output links (%)	Network size	Reciprocity (%)	Transitivity (%)
Information Exchange	31.5	47.5	35.2	45.9	274	31.10	46.2
Coordination	27.5	37.1	53.6	35.8	239	33.52	45.3
Participation	10	18.8	28.9	18.2	87	10.13	25.9

870 total expected links of 30 organizations.

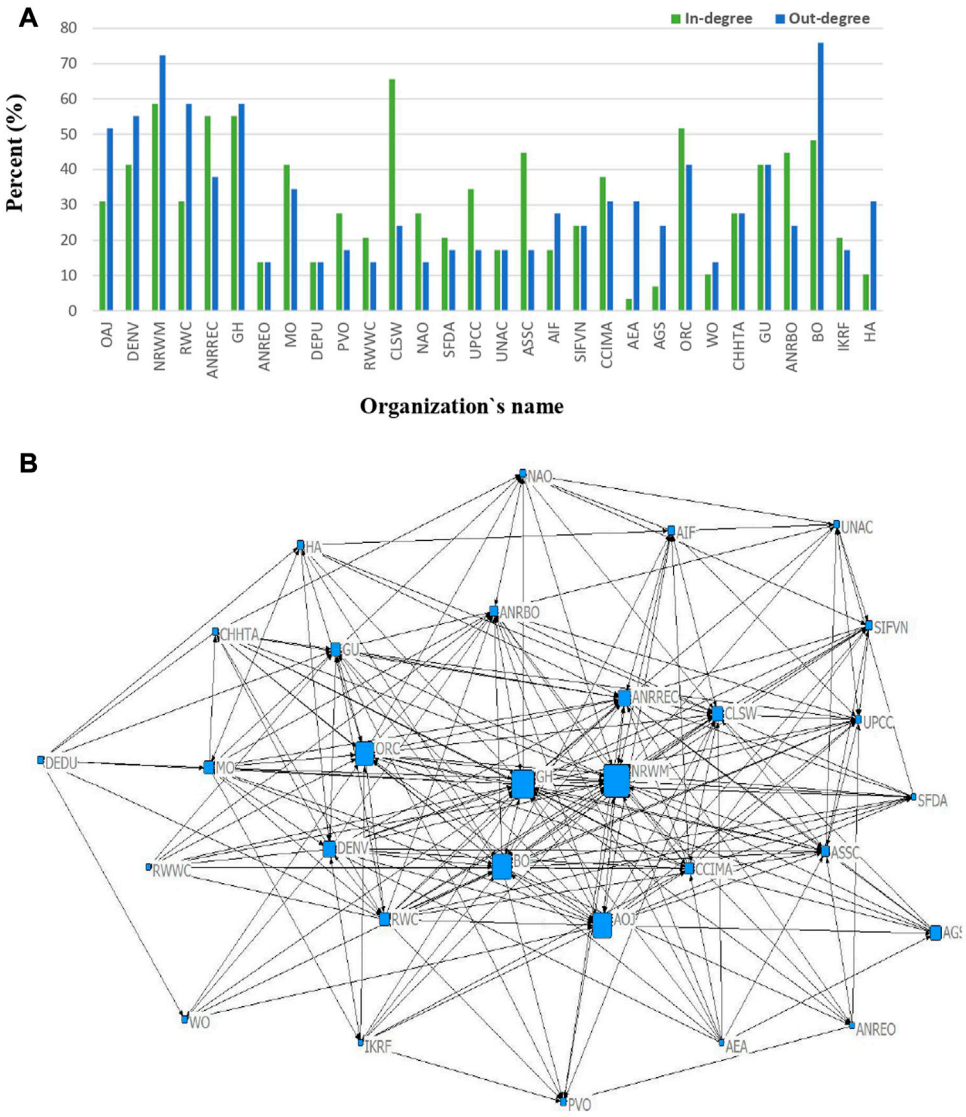

FIGURE 2
SNA results of Information Exchange network **(A)** In-degree and out-degree centrality **(B)** Between centrality (*Larger size indicates higher between centrality*).

the links of information exchange. In addition, the General Department of Cooperatives, Labor, and Social Welfare (CLSW), the Department of Natural Resources and Watershed Management (NRWM), the Government House (GH), the Agriculture and Natural Resources Research and Education Center (ANRREC), and the Organization of Rural Cooperative (ORC)—with in-

TABLE 5 Primary and secondary organizations in terms of information exchange of watershed management.

Primary organizations	Secondary organizations
Organization of Agriculture Jihad	Agriculture and Natural Resources Engineering Organization
Department of Environment	Department of Education
Department of Natural Resources and Watershed Management	Provincial Veterinary Office
Regional Water Company	Rural Water and Wastewater Company
Agriculture and Natural Resources Research and Education Center	Nomadic Affairs Organization
Government House	Support Fund Development in Agriculture
Meteorological Organization	Union Production Cooperative Companies
Department of Cooperative, Labor, and Social Welfare	Union of Nomadic Agriculture Cooperative
Organization of Rural Cooperative	Agriculture Support Services Company
Golestan University	Agriculture Insurance Fund
Agricultural and Natural Resources Engineering Basij Organization	Social Insurance Fund for Farmers, Villagers, and Nomads
Broadcasting	Chamber of Commerce, Industries, Mines, and Agriculture
	Agricultural Experts' Association
	Agricultural Guild System
	Welfare Organization
	Cultural Heritage, Handicrafts, and Tourism Administration
	Imam Khomeini Relief Foundation

degree centrality levels of 65.5%, 55.2%, 55.2%, and 51.7%, respectively—had a higher score than the other actors in the network and had high authority in the network. Therefore, these actors have higher social capital and are considered key actors in the information exchange network for watershed management, so that many actors in the network refer to these actors to receive information.

The introduction of relevant organizations in terms of primary and secondary organizations is regarded as one of the most important findings of each network analysis. In this regard, the main organizations have a more important role and function in watershed management, and secondary organizations are at a lower level of information exchange to the primary organizations. The list of organizations in different groups of primary and secondary organizations is presented in Table 5.

The Organization of Agriculture Jihad (OAJ), the Department of Environment (DENY), and the Department of Natural Resources and Watershed Management (NRWM) of the province have been ranked first to third, respectively, as the primary organizations involved in watershed management of the study area. Conversely, the Agriculture and Natural Resources Engineering Organization (ANREO), the Department of Education (DEDU), and Provincial Veterinary Office (PVO) were specified as the first to third secondary organizations involved in the watershed management of this province, respectively (Table 5).

Graphs can be used to better understand the geometry of actors and their social power in the network. As shown in Figure 2B, some organizations were displayed with larger points and others had very small points. The difference in the size of points is determined by the level of intermediate centrality of organizations, so that organizations which can interact more with other organizations are represented with larger points. Based on these interpretations, the Department of Natural Resources and Watershed Management (NRWM), the Government House (GH), the Organization of Agriculture Jihad (OAJ), Iran Broadcasting (BO), and the Organization of Rural Cooperative (ORC) have a strong place in the network and can influence the flow of information exchange among the other actors (Figure 2B). Thus, they control the flow of information in the network based on the shortest paths among other organizations. Such organizations are referred to as the information hubs in the network and play a significant role as brokers controlling and transmitting information in the network.

The research results aimed at analyzing the information exchange network among organizations active in sustainable management of natural resources in the Alborz Dam in Mazandaran province, Iran, based on the social network analysis approach indicate that the access and information sharing among the studied organizations is not easy and there is a moderate level of communication between organizations. In the information network of these organizations, the Organization of Agricultural Jihad is as a moderate power in the network. Gorgan University, the Organization of Agricultural Jihad, and the Agriculture and Natural Resources Research and Education Center play a vital role in facilitating and sharing information with other organizations, while at the same time they are not dynamic in

TABLE 6 Primary and secondary organizations in terms of coordination of watershed management.

Primary organizations	Secondary organizations
Organization of Agriculture Jihad	Department of Environment
Department of Natural Resources and Watershed Management	Agriculture and Natural Resources Engineering Organization
Regional Water Company	Meteorological Organization
Agriculture and Natural Resources Research and Education Center	Department of Education
Government House	Provincial Veterinary Office
Social Insurance Fund for Farmers, Villagers, and Nomads	Rural Water and Wastewater Company
Organization of Rural Cooperative	Department of Cooperative, Labor, and Social Welfare
Cultural Heritage, Handicrafts, and Tourism Administration	Nomadic Affairs Organization
Golestan University	Support Fund Development in Agriculture
Agricultural and Natural Resources Engineering Basij Organization	Union Production Cooperative Companies
Broadcasting	Union of Nomadic Agriculture Cooperative
	Agriculture Support Services Company
	Agriculture Insurance Fund
	Chamber of Commerce, Industries, Mines, and Agriculture
	Agricultural Experts' Association
	Agricultural Guild System
	Welfare Organization
	Imam Khomeini Relief Foundation

the process of information exchange with other organizations. In analyzing the legislative processes and their relationship with the information exchange network of organizations, it became clear that the Department of Natural Resources and Watershed Management has more power than other organizations in this field (Rezaei et al., 2015). Based on the study, there are few organizations with a large amount of power in the information network of organizations involved in the sustainable management of natural resources. In other words, this network requires an organization which can take responsibility for providing information and knowledge to other organizations in the network. Also, the findings of our study are in line with the study by Nabiafjadi et al. (2021) in terms of the power analysis that demonstrated how the dominant role of governmental bodies and the weak contribution of private organizations and civil society result in up-down decision-making.

3.2.2 Coordination network

The density of the coordination network among organizational stakeholders was 27.5%, indicating breakdown between actors and weak organizational cohesion based on this link. From all 870 possible and potential links, only 239 links were activated for the coordination network. Regarding the direct relationship between the network size index and the institutional network cohesion, it can be stated that by strengthening the organizational coherence among the above-mentioned institutions, coordination between these institutions can be facilitated, possible parallel work can be prevented, and watershed management activities can be made feasible at a lower cost and in quicker time. The network centralization index based on input and output links in the matrix of coordination was 53.6% and 35.8%, respectively, for both links. The reciprocity of links is another index being studied among organizational agents. The value of 33.52% represents a weak link between organizations in the coordination network. Thus, the stability of organizational stakeholders associated with the studied network was low. The transitivity of links indicates the sustainability of the network and was 45.3% for the coordination network. Such an index confirmed an average stability of the coordination network in watershed management activities (Table 4).

In the coordination network, the Organization of Agriculture Jihad (OAJ), the Department of Natural Resources and Watershed Management (NRWM) of Golestan Province, and the Regional Water Company (RWC) were ranked first to third as the main organizations, respectively. Eleven organizations were considered the main organizations and 19 other organizations were considered secondary organizations in the coordination network of watershed management. The Department of Environment (DENY) of the province, the Agriculture and Natural Resources Engineering Organization (ANREO), and the Department of Cooperatives, Labor, and Social Welfare (CLSW) were included as secondary organizations (Table 6).

Based on Figure 3A, in the coordination network, the institutions involved in watershed management activities including the Department of Natural Resources and Watershed

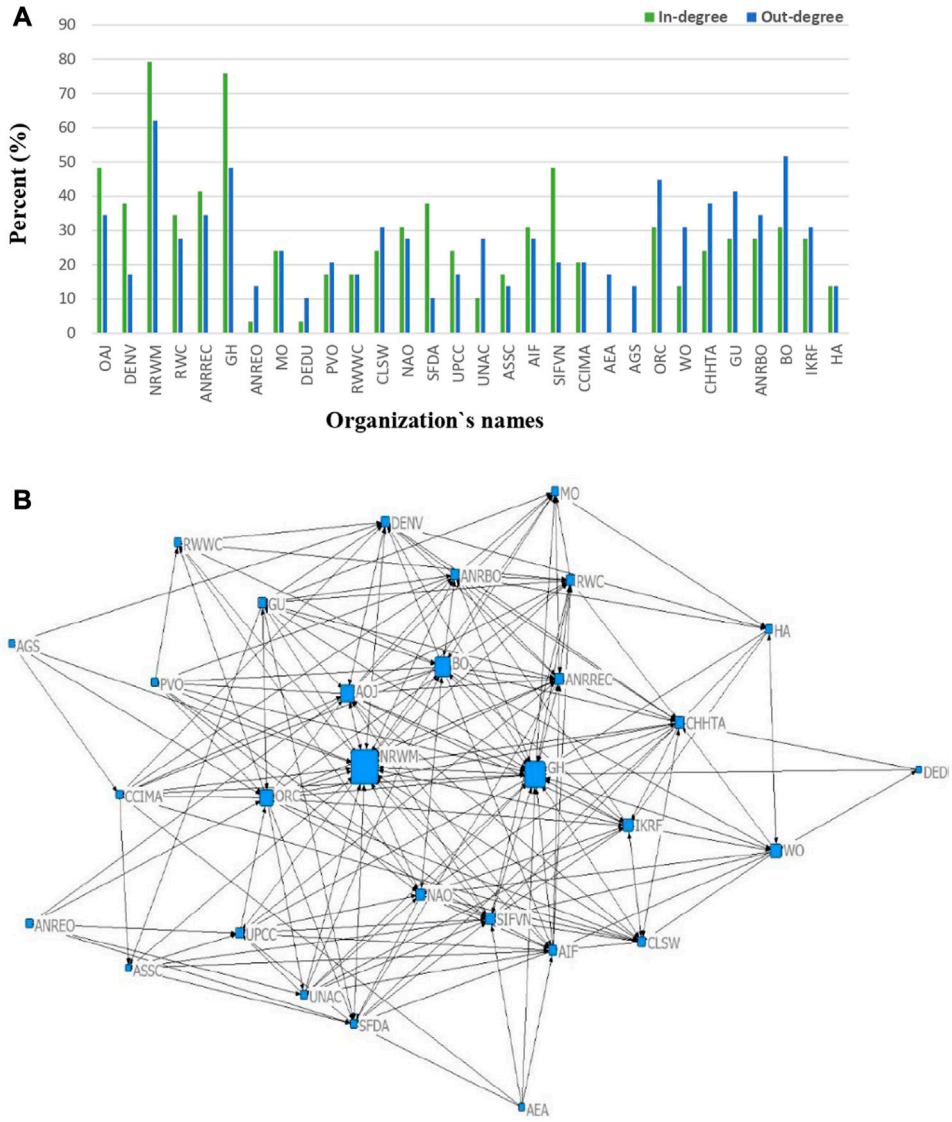

FIGURE 3
SNA results of the coordination network. **(A)** In-degree and out-degree centrality. **(B)** Between centrality (*Larger size indicates higher between centrality*).

Management (NRWM), Iran Broadcasting (BO), the Government House (GH), Organization of Rural Cooperative (ORC), Golestan University (GU), and the Cultural Heritage, Handicrafts, and Tourism Administration (CHHTA) had higher social influence, with out-degree centralities of 62.1%, 51.7%, 48.3%, 44.8%, 41.4%, and 37.9%, respectively. The Department of Natural Resources and Watershed Management (NRWM), the Government House (GH), the Organization of Agriculture Jihad (OAJ), the Social Insurance Fund for Farmers, Villagers, and Nomads (SIFVN) of Golestan Province, and the Agriculture and Natural Resources Research and Education Center (ANRREC) had the maximum reputation and authority, with in-degree centralities of 79.3%, 75.9%, 48.3%, 48.3%, and 41.4%, respectively. Furthermore, based on the intermediate centrality index, the Department of Natural Resources and Watershed Management (NRWM) (17.04), Government House (GH) (12.168), Iran Broadcasting (BO) (7.516), Organization of Rural Cooperative (ORC) (6.258), and the Organization of Agriculture Jihad (OAG) (5.688) were the key effective actors in the coordination network of the organizations involved in watershed management activities (Figure 3B).

In a similar study, the effects of the formal and informal power of organizations on budget allocation in the field of natural resources were analyzed in the fourth development plan of Kohgiluyeh and Boyer-Ahmad province in Iran. The results of this study revealed that having a relationship with the main focus of power is effective in regard to allocating budget, and more informal power can more effectively affect the allocation of funds than formal power (Mohammadi Kangarani et al., 2011). Also, the formal and informal networks of organizations in Kohgiluyeh and Boyer-Ahmad province

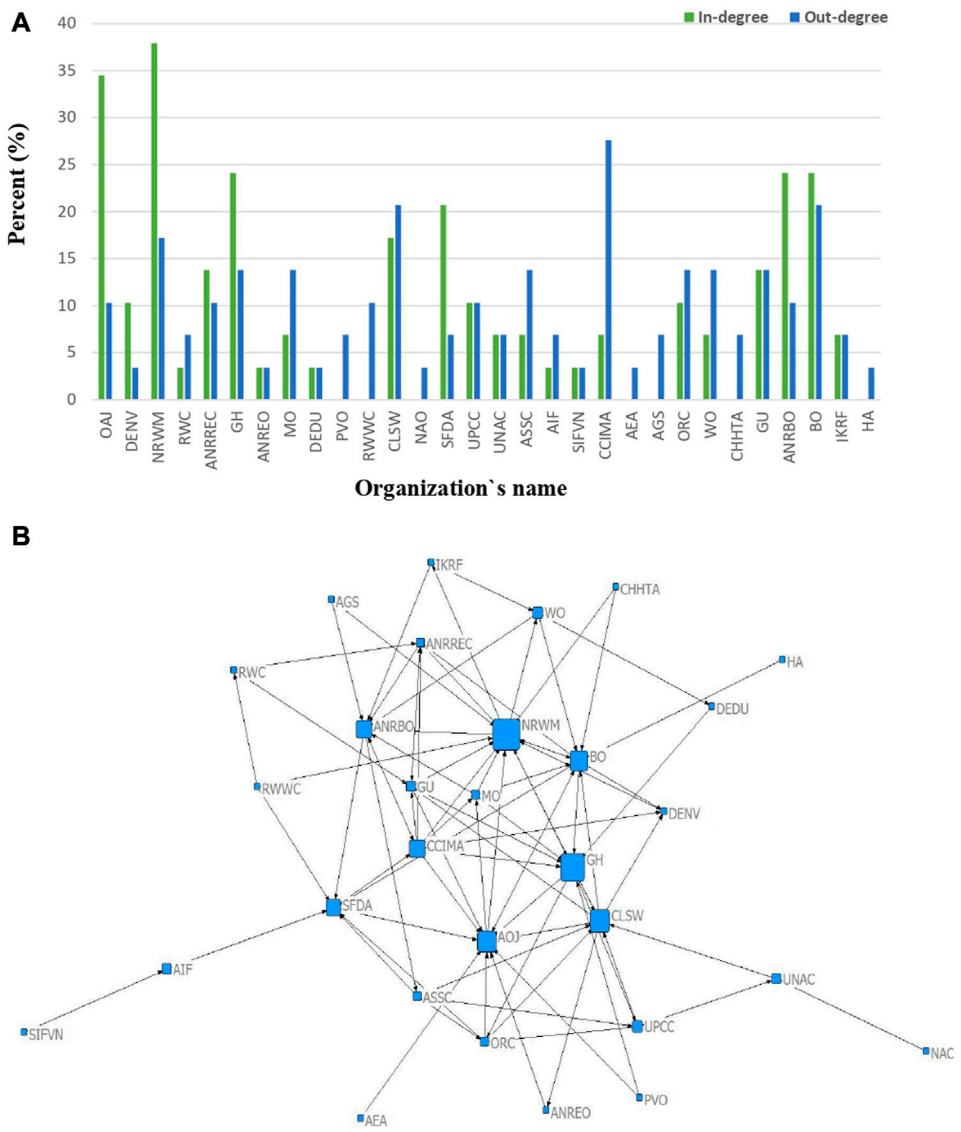

FIGURE 4
SNA results of the participation network. **(A)** In-degree and out-degree centrality. **(B)** Between centrality (*Larger size indicates higher between centrality*).

was investigated using social network analysis. Based on the results, the non-similarity of these organizations in these two networks affects the environmental management decisions of the province. In addition, this research confirmed the efficiency of the network analysis approach in solving managerial problems.

3.2.3 Participation network

The network size for the 30 organizations involved in the comprehensive watershed management activities was obtained as 87 links out of the total 870 links. The low level of the link density index (10.0%) indicated a very low level of organizational coherence based on these links (network). Furthermore, the obtained value for the network centralization indices based on input and output links was 28.9% and 18.2%, respectively. Finally, based on the indices of link reciprocity and transitivity, indicating the balance in the network (which was 10.13% and 25.9%, respectively), the sustainability of participation network was inferred at a low level, suggesting the vulnerability of the desired network (Table 4). Meanwhile, the Department of Natural Resources and Watershed Management (NRWM), the Organization of Agriculture Jihad (OAJ), the Government House (GH), Iran Broadcasting (BO), and the Agricultural and Natural Resources Engineering Basij Organization (ANRBO) had a higher reputation and authority than other actors, so that the actors in the network were more dependent on these actors. The Chamber of Commerce, Industries, Mines, and Agriculture (CCIMA), Iran Broadcasting (BO), the Department of Cooperative, Labor, and Social Welfare (CLSW), the Department of Natural Resources and Watershed Management (NRWM), and Golestan University (GU) were the most participatory organizations in the field of comprehensive

TABLE 7 Primary and secondary organizations in terms of participation in watershed management.

Primary organizations	Secondary organizations
Organization of Agriculture Jihad	Department of Environment
Department of Natural Resources and Watershed Management	Regional Water Company
Government House	Agriculture and Natural Resources Engineering Organization
Golestan University	Support Fund Development in Agriculture
Agricultural and Natural Resources Engineering Basij Organization	Department of Education
Meteorological Organization	Provincial Veterinary Office
Department of Cooperative, Labor, and Social Welfare	Rural Water and Wastewater Company
Chamber of Commerce, Industries, Mines, and Agriculture	Union Production Cooperative Companies
Broadcasting	Nomadic Affairs Organization
	Organization of Rural Cooperative
	Agriculture and Natural Resources Research and Education Center
	Union of Nomadic Agriculture Cooperative
	Agriculture Support Services Company
	Agriculture Insurance Fund
	Social Insurance Fund for Farmers, Villagers, and Nomads
	Agricultural Experts' Association
	Agricultural Guild System
	Welfare Organization
	Cultural Heritage, Handicrafts, and Tourism Administration
	Imam Khomeini Relief Foundation

watershed management activities. The above-mentioned organizations had a higher social impact on promoting the participation links with other organizations (Figure 4A).

In the participation network, which was almost the same as the coordination network, the Organization of Agriculture Jihad (ORJ), the Department of Natural Resources and Watershed Management (NRWM) of Golestan Province, and the Government House (GH) were ranked higher as the main organizations (Table 7). The number of main organizations in the participation network (nine organizations) was lower than the other networks of information exchange (12 organizations) and coordination (11 organizations), so that some organizations, such as the Department of Environmental (DENY) and the Agriculture and Natural Resources Research and Education Center (ANRREC) of the province, were included in the participation network as secondary organizations.

Regarding the management of watershed management activities in the inter-organizational participation network, the Department of Natural Resources and Watershed Management (NRWM), the Government House (GH), the Department of Cooperative, Labor, and Social Welfare (CLSW), the Organization of Agriculture Jihad (OAJ), and Iran Broadcasting (BO), with intermediate centralities of 18.139, 15.094, 11.607, 10.506 and 10.226, respectively, were the most important involved organizations which could play an important role in the network as highly appropriate brokers. Based on these results, the above-mentioned organizations can be very effective in developing their participation in the organizational network (Figure 4B).

The studies by Rezaei et al. (2015) and Karimi Gougheri et al. (2018a) showed that more participatory activities are required in this network for the equal distribution of information among different organizations, so that they can be encouraged in an interactive and dynamic way to better manage natural resources such as development of mutual scientific activities in defining research plans and executive programs with collaboration of different organizations in terms of sustainable natural resources management.

3.3 Discussion

The QAP correlation index was used to investigate the correlation between the studied networks (Table 8). The correlation between the networks of information exchange, coordination, and participation was positive and significant at 1% level. In addition, coordination and participation had the highest correlation, while information exchange and participation had the lowest correlation. Thus, if there is an exchange of information between the two organizational actors, the links of coordination (0.193) and participation (0.107) can established in the network.

The results of the study indicated that the density index in information exchange, coordination, and participation networks is

TABLE 8 Correlation of studied networks in terms of QAP index.

Network	Information exchange	Coordination	Participation
Information Exchange	1	—	—
Coordination	0.193**	1	—
Participation	0.107**	0.250**	1

The coefficients with two stars were significant at 0.01 level.

less than average. In the participation network, the values of the density index are very low and coherence is the same among the networks (information exchange, coordination, and participation). Based on the results of this index, no dense network can be expected in the studied links, especially in the network of participation. Therefore, with regard to the direct relationship of social cohesion with density, the degree of social cohesion based on the matrix of participation is very weak. As a result, integrated water management activities face some challenges and effort should be made to increase density in the above-mentioned networks to form the system. Based on the results of link reciprocity among the organizational actors, the total amount of information exchange links and coordination was below the moderate level, and the level of interaction among organizational actors was very low. Based on these results, as well as that of the link transitivity index, all networks of information exchange, coordination, and participation has showed minimum sustainability. Some mutual links in the decision-making processes for water management activities should be conducted to strengthen organizational integrity.

The total network size indicated that nearly one-tenth of the expected links were found in the participation network. The value of this indicator in the networks of information exchange and coordination was more favorable, although less than half of the expected links were established in the above-mentioned networks. Based on the results of the research into the information exchange, coordination, and participation networks, the ratio of centrality increased on the basis of the input links to the output links. In other words, based on the input links related to coordination, the participation in the investigated organizational network was almost weak and was dependent on limited activists. However, the distribution of coordination and participation in terms of output links had less dependence on the presence of the actors with high centrality in the above-mentioned networks. On the other hand, the centrality of the entire network of information exchange, based on output and input links, had a more dispersed structure and were similar to each other, indicating the moderate influence of the actors with a central position in terms of reputation and influence. In other words, nearly half of the input and output links of the information exchange are available for central organizations and the rest of the links are shared with other organizations in the network of information exchange.

4 Conclusion

Relationship between humans and nature is an inevitable phenomenon that has a long history since the beginning of human life. However, human intervention has expanded overtime in terms of the various exploitations of natural resources and the environment through scientific and technological developments. Human societies have taken advantage of natural resources by performing individual or collective activities through formal and informal organizations in order to meet their needs and desires. The multiplicity of organizations and the different missions and goals that are defined by each has led to the increased exploitation of nature. The classic management system of organizations has typically been that their managers and members have planned and performed independently in their working areas to achieve institutional goals. Sometimes, organizations have made independent decisions due to a lack of proper communication and information about the programs of other organizations, which have often been parallel to and repeated by other organizations. In this regard, better governance of natural resources has been suggested in recent decades in order to realize the sustainable use of natural resources. Governance refers to a wide system that includes formal and informal institutions in that while each of them has its own structure, strategy, and resources, they also play an important role in the process of resources management and common goal achievement. Thus, the identification of different groups of inter-organizational actors, mutual interactions, and communication networks between them is proposed. In the study of natural resource governance, it is necessary to use the methods and techniques that are appropriate to the nature of the subject. SNA is the most common method used in these studies to identify actors related to different areas of natural resources and the communication between its stakeholders. The purpose of this article was to identify the organizations involved in the management of the Chehelchay watershed in Golestan province, Iran, and to analyze the communications and interactions between the organizations in terms of intensity and type. Using the SNA method, 30 organizations related to the studied watershed were identified and information was collected through a questionnaire from specialist panels (84 people) in the aforementioned organizations. The indicators of centrality, density, in-degree, out-degree, between centralities, network size, reciprocity, and transitivity were measured in three networks: information exchange, coordination, and participation. Data were analyzed by UCINET and network maps were drawn with NetDraw.

The main findings showed that the index of centrality in the networks of information exchange, coordination, and participation was 31.5%, 27.5%, and 10%, respectively. The density index for the information exchange network was 47.5%, for the coordination network it was 37.1%, and for the participation network it was

18.8%. The network size of the information exchange, coordination, and participation networks were calculated at 274, 239 and 87, respectively. Moreover, the reciprocity and transitivity indices were measured as follows, respectively: information exchange network (31.10% and 46.2%), coordination network (33.52% and 45.3%), and participation network (10.13% and 25.9%). By reviewing the trends of the numbers related to the indicators calculated in the studied networks, it is clear that the participation network of organizations involved in the watershed is weaker than the other two networks in terms of all dimensions. However, the amount of these indicators for the two networks of information exchange and coordination were also at an average level. Therefore, it can be concluded that the interactions between the organizations involved in the considered watershed have been moderately weak. It seems that these interactions are only for the exchange of necessary information or coordination in the implementation of some separate programs. According to the findings, these collaborations are very limited and scattered, and no significant participation is observed between the mentioned organizations. To improve the sustainable governance and management of the watershed area, it is suggested that the beneficiary organizations hold periodic and monthly meetings in the form of small and large organizational groups in order to be informed and updated with the information and programs of other organizations; their communications should not be limited only to the information exchange and coordination of their separate programs. Moving toward active, mutual, and comprehensive participation is required, in which different stakeholders, including government institutions, private organizations, and NGOs, are considered.

The network graphs and maps related to the in-degree, out-degree, and between centrality indicators also showed that the government institutions were the main organizations in all three studied networks and were considered as brokers with other organizations. Indeed, based on the results, the public organizations in all of studied networks (information exchange, coordination, and participation) had a greater impact than non-governmental organizations (private, for-profit, and non-profit). The results indicated that non-governmental organizations should be considered as key actors in integrated watershed management by considering the functions of comprehensive watershed management, as well as the deep links with the target communities of agricultural and rural areas. However, these organizations are marginalized in practice and have the least degree of authority, influence, and ability to control the network in the studied networks. Such organizations also had lower social capital and received less support and were less emphasized in the policy-making and decision-making of watershed management. This finding revealed a kind of weakness in the networks under consideration, because the involvement of all stakeholders, especially private, for-profit, and non-profit organizations, is necessary to achieve the goals of comprehensive watershed management. In this regard, it is recommended that appropriate policies be made by the main organizations responsible for the comprehensive watershed management (including the Department of Natural Resources and Watershed Management, Organization of Agriculture Jihad, Government House, and Agriculture and Natural Resources Research and Education Center) to change the positions of these actors in the organizational networks, as neglecting these organizations challenges the implementation of comprehensive watershed management in the Chehelchay watershed and less success is achieved at greater time and cost. In addition, developing incentive mechanisms for the greater participation of NGOs in the decision-making processes and implementation of comprehensive watershed management activities in the Chehelchay watershed is suggested, so that these organizations can enter the network center in the long run and play a more significant role. As a result, the changes in organizational arrangements in the network and the distribution of power among public organizations and NGOs would be optimal and balanced. Public organizations can reduce their incumbency by adopting appropriate policies and taking the task of monitoring and evaluating. The development of strategies, activities, and services for the integrated watershed management based on stakeholders' participation and coordination of responsible organizations in natural resources is proposed as a fundamental step for realizing the effective participation of stakeholders. The Department of Environment of the province is responsible for protecting the environment and can play a significant role in the development of natural resources as the active organization. Therefore, the coordination of the activities of this institution with other organizations is essential. Overall, a systematic shift is required from governmental management toward governance in order to achieve sustainable natural resource and watershed management. In this regard, organizations should go beyond information exchange and the mere coordination of their programs and move towards a participatory network.

Scheduling an interview with a panel of experts that were mainly the top managers of their institutions from a large number of organizations (30 organizations for this study) was a time-consuming process. Asking the respondents the questions of the questionnaires one by one in order to avoid missing data was another limitation and challenge of the study. In other words, the research team could not give the questionnaire to the experts to fill out individually and needed to gather all of the panel members of each organization in a special meeting in order to interview them and collect the data. As for the research implications, the human-nature relationship as the base of environmental sociology should be considered a topic of interest for not only academia but other groups of people worldwide. Human beings affect natural resources and the environment in different ways, especially through the organizations and decisions that they make for different purposes. In this regard, SNA is an applicable tool which simply visualizes the communication and interactions of individuals, organizations, or societies (rural or urban). Researchers, authorities, and politicians should be able to provide applicable decisions/solutions based on research findings such as the current study in order to achieve sustainable resource management and governance. It is suggested for future studies to repeat this study in other watersheds of Iran or other developing countries. It is also helpful to analyze the social network analysis of individuals or rural/urban working groups as well as the organizational level.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Ethics statement

This study was approved in the committee related to National macro plan for comprehensive management of watersheds of Iran.

Author contributions

KR-M: Develop research design, data collection, data analysis and interpretation, write and finalized the manuscript. MF: Data collection, data analysis and interpretation, write and finalize the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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