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RESEARCH ARTICLE



Polycentric governance systems: addressing the power gap centered on climate entrepreneurs in Semnan Province of Iran

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ABSTRACT

Polycentric governance systems seek to solve environmental challenges through the involvement of diverse actors at different decision-making levels. However, previous studies did not confirm the positive performance of polycentric governance in social interactions with certainty. Therefore, the aim of the study was to identify the capacity and performance of current actors and units to understand their impact on the performance of polycentric governance systems perspective as a whole. For this purpose, this study investigated the theory of polycentric governance systems on a large scale in Semnan province of Iran. The social network analysis (SNA) and its 12 indices were used as a methodology of research, including 352 heterogeneous actors with different capacities, were interviewed and studied. The results showed that the power and leadership of key actors play an effective role in the stability and development of polycentric governance systems. The power sharing between decision-making centers is implemented through the interlevel communication of climate entrepreneurs. The comparison of performances showed that public management could not meet the leadership criteria as well as private actors. The final results showed that the total performance of the polycentric governance system of environment was positive and influenced by the performance of pioneer NGOs and climate entrepreneurs.

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Topology; Cohesion and stability; Power and leadership; Policy-making; Performance

1. Introduction

Entrepreneurship is considered a mediation of green marketing mix and eco-labeling in the policy process (Khan et al., 2019; Ranjan, 2015). One conception of entrepreneurship is that it is not a permanent feature of a particular person or role, but a situation that is accessible in specific social contexts and is the responsibility of the actors involved (Dy & Agwunobi, 2018). To understand climate and governance policies and the factors that create modifications in entrepreneurial activities, strategies, and success, one must look for actors who are able to take action by increasing the influence of governance and changing the distribution of authority and information. Furthermore, people who are able to take actions aim at changing or disseminating cognitive norms and frameworks, worldviews, or institutional logic (Boasson & Huitema, 2017). Governance is generally defined as a set of formal and informal arrangements based on cooperation in a network of governing stakeholders (Wolfert et al., 2017).

In contrast to hierarchical top-down processes (monocentric systems), bottom-up developments combined with a large number of diverse actors and tools lead to a polycentric governance system (PGS) (Jordan et al., 2018). PGS highlights

a multilayered phenomenon in which communication initiatives replace isolated behaviors in actors (Pahl-Wostl et al., 2020). Thus, PGS involves interactions among heterogeneous decision centers in a system, both across levels (vertical) and within a given level (horizontal) (Albareda & Sison, 2020; Koontz, 2021), which requires a sufficient level of stability and formalization (Gray & Purdy, 2018; Voets et al., 2021).

The polycentric approach highlights the self-organization or mutual adaptation that results from the interaction and learning of the actors. Coordination in a polycentric system depends more on entrepreneurship. PGS will also lead to more entrepreneurship in the decision-making and social domains, while a reversal to monocentric governance will reduce the volume and diversity of entrepreneurship (Jordan et al., 2018). Scientists are increasingly seeking to find out how entrepreneurial governance targets different decision-making positions or how their strategies have led to the creation and development of climate networks (e.g. Anderton & Setzer, 2018; Jordan et al., 2018; Tesfaye et al., 2020).

The inclusion of the concept of polycentricism in this study clarifies the link between decision centers and system performance. With regard to this concept, Su et al. (2017), Gatignon

and Capron (2023), and Huang et al. (2021) mentioned that initial attempts have been made to assess the effect of the capacity and performance of units or centers in PGS. However, it is still insufficient to fully understand their impact on the performance of the vision of PGS as a whole. However, some studies (e.g. Mudliar, 2021; Scott & Thomas, 2017) have not confirmed the positive performance of collaborative governance with certainty. These uncertainties are about the performance of the polycentric systems and features such as leadership role, power, distribution of resources, and authority. For instance, Scott and Thomas (2017) pointed out that although collaborative governance has improved actors' access to network resources in their study, this process can occur elsewhere in a way that increases inequality in access to resources. The concept of power dynamics (underpin of PGS) is one of the hottest scientific topics in today's world (Morrison et al., 2019), which is discussed in this research. Understanding polycentric systems has become more complex and muddled due to the difficulties of monitoring, defining, and generalizing power as well as its extremely difficult management (Morrison et al., 2019). The complexity and confusion of polycentric systems mean that power dynamics are more effectively concealed than other forms of governance (Morrison et al., 2019). Therefore, bridging the power gap is essential because it might result in the creation of a variety of novel ideas, tools, and opportunities for experts and policy-makers who are interested in developing and working within polycentric environmental governance.

There is also research on PGS that challenges the reported assumptions about power and PGS. For example, Mudliar (2021) limits the performance of polycentric systems and argues that different forms of power impact not just the genesis and design of polycentric systems, but also decisions concerning policy choices and results. Mudliar (2021) also argued that although it creates a multicentered power structure, it also deprives lower officials of their authority and weakens decision-making institutions and centers. Mudliar (2021) argues that when decision-making power is distributed among multiple centers, the communication and coordination between different levels of government become challenging and often impractical. This can result in high transaction costs and, in some cases, even exacerbate conflicts and rivalries between state and local governments. In other words, according to Mudliar, the complexities and difficulties associated with interlevel communication can hinder effective governance and collaboration between different governing bodies. More specifically, in the area of functional cross-links, information-sharing mechanisms are problematic. However, in previous studies, analysts looked at the structural aspects as well as the power or other traits of various sorts of actors acting alone or frequently engaging with a group of institutions or people in order to comprehend the PGS system. While analyzing the stability of the structure, power dynamics, leadership, and access characteristics in all different institutional and non-institutional groups in a large data set, this study evaluates the performance of decision centers and its impact on the final vision and the presentation of practical policies. This is an issue that has been less addressed and is considered a comprehensive review. Accordingly, the main aim of this study was to

help to better understand the performance of PGS and the effects of the decision centers and heterogeneous actors of this process by studying on a large scale and evaluating large amounts of data at the local to national levels as well as various parameters by responding to the following questions:

1. What are the PGS units and at what levels are they located?
2. What is the separate distribution and performance of each unit at the four levels of local, county, province, and national?
3. What is the effect of each decision-making center, especially climate entrepreneurs, on the overall governance perspective in terms of the characteristics of power, leadership, and access to resources (network features)?
4. What are the findings of the study of the topology of the PGS structure? How stable is the governance network structure?
5. How can the stability and development of a multilevel network be accelerated in environmental governance?

Finally, the main proposals will be presented based on the theory of PGS to achieve a more profitable future for all environmental stakeholders and practitioners through a better understanding of the network and its complex interactions.

2. Research method

2.1. Study area

The province of Semnan, which is part of Iran's northern Alborz Mountain Range and borders the Dasht-e-Kavir Desert in its southernmost reaches, forms the study's perimeter. This province currently has eight counties, 20 cities, 15 districts, and 31 villages. Figure 1 shows the geographical location of Semnan province in Iran. Climatic diversity in the study area is significant. Exposure to the arid climate, reduced rainfall, prolonged drought, seasonal river drying, severe decline in surface and quality of pastures, and uncontrolled exploitation of resources, especially aquifers, are among the forthcoming climate issues (Safarianzengir et al., 2022).

2.2. Data collection and analysis

The social boundary of this study includes four levels of Iranian sub-national level (from local to national). The local areas, counties, and the center of Semnan province are the three layers that were studied in Semnan province. Macrolevel information (fourth level) originated from Tehran province, which is the capital of Iran. The actors studied included all actors who were active in policy-making, managers and stakeholders of natural resources management, and environmental conservation and climate policy sectors. In addition, due to the need to pay attention to diverse actors in PGS, all institutional and non-institutional actors from both private and public sectors were identified and interviewed (Appendix 3).

Communication information at the sub-national level of Iran was collected through field surveys using face-to-face interview tools and a researcher-made questionnaire from December 2020 to June 2021. In this study, the snowball sampling method was used to identify respondents and governing actors. A total of 352 people, including 127 women

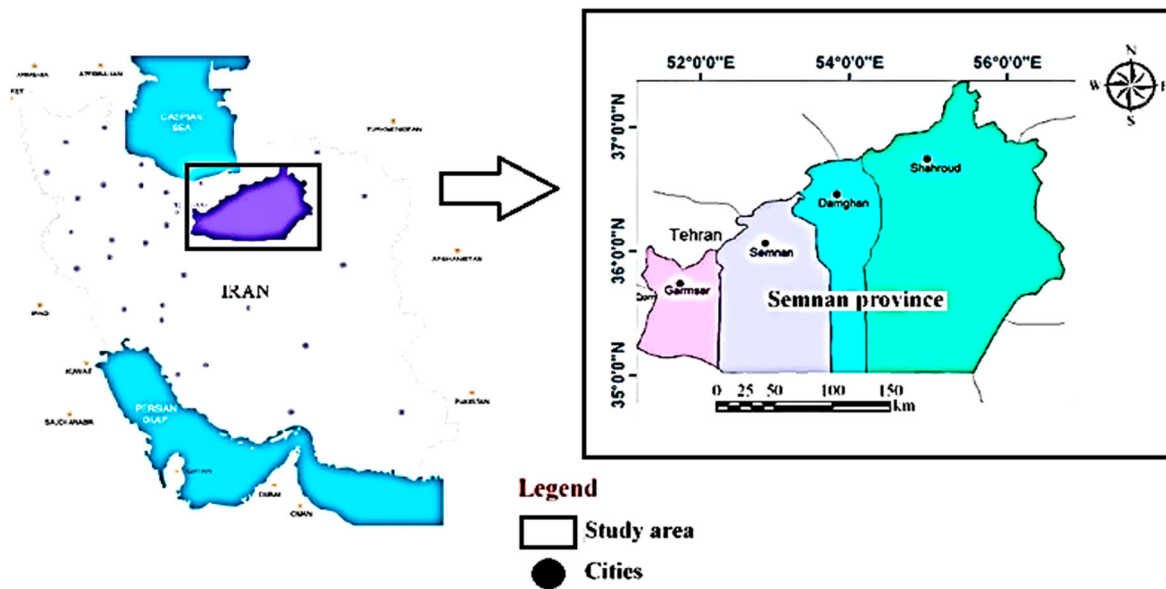


Figure 1. Geographical location of the study area in Iran. Source: Research findings.

(36.08%) and 225 men (63.92%), were interviewed. In its final form, the questionnaire includes five different categories, including questions about individuals (demographic) and their role in entrepreneurship, their relationships with other individuals, and institutions and governmental and non-governmental institutions (Appendix 1). The duration of the interview was approximately 45 minutes.

The social network analysis (SNA) method in this study has been used to analyze the communication data, discover the network structure of all its actors (Kurt & Kurt, 2020), and map the collaborative relationships that can help develop communication knowledge (Franco-Trigo et al., 2020; Wang et al., 2020). In fact, SNA is a proven method of social sciences (De Nooy et al., 2018) to better understand the causes of the underlying structures and processes in the environmental governance system and the social and environmental consequences of these systems (Bodin et al., 2020). PGS performance and structural stability in this study were evaluated by considering the network connection of each governance unit. The unit of SNA is the relationship between actors, and this study also addressed the links that occurred directly or indirectly, intentionally or unintentionally, between entrepreneurial actions in the field of rural actors' natural resources at the local, county, and provincial levels. Therefore, the number and intensity of communication of each actor, as well as the identified governing units, were examined separately.

In addition, in the study, macrolevel indicators have been used (nine indicators including Density, Centralization, Components, Fragmentation, Avg Distance, SD distance, Diameter, Breadth, and Compactness) to evaluate the coherence of the governance structure. Network coherence is in line with the framework presented by Fonseca et al. (2019) according to which communication and interdependence among an individual, society, and institutions are important. The middle-level E-I index was used to identify the communication approach of the actors in governance. To evaluate the effectiveness of individual actors and network units in terms of their communication power, including influence, authority, reputation, and

popularity, as well as their role as brokers and access to resources, a comprehensive analysis was conducted. Additionally, the behavior of actors was examined to understand their leadership and governance capabilities. For this purpose, five indicators at the microlevel were utilized: Degree centrality, In-degree, Out-degree, Betweenness centrality, and Closeness centrality. These indicators provide valuable insights into the communication dynamics and network structures within the studied context. For a more systematic evaluation of these maps, the definitions of the mentioned indices and the scores of each index are summarized in Appendix 2. Data analysis was performed in Excel, SPSS 16.0, Ucinet 6.528, and Gephi 0.9.2 software applications.

3. Results

3.1. Identified actors, their characteristics, and visualized network model of PGS

The results showed that the government relations network is affected by the activities of 76 actors at four levels of local, county, province, and national collaboration. The five types of actors that represent the units or decision-making centers in PGS are institutional actors, environmental NGOs (ENGOs), climate entrepreneurs, village councils, and independent individuals. Full details of identified actors of PGS are provided in Appendix 3. Identifying and classifying actors in the first step of the research helped to better understand the nature of actors, their links at different levels of PGS, and especially the role of climate entrepreneurship. Collaborative network visualization showed that the governing actors were different in terms of communication intensity and degree of centrality (relational power). Figure 2 shows the network visualization model of diverse multilevel actors in PGS in Iran. The actors were shown in different sizes, which indicates the number of references and communications, and their different colors help to distinguish the type and level at which they are present.

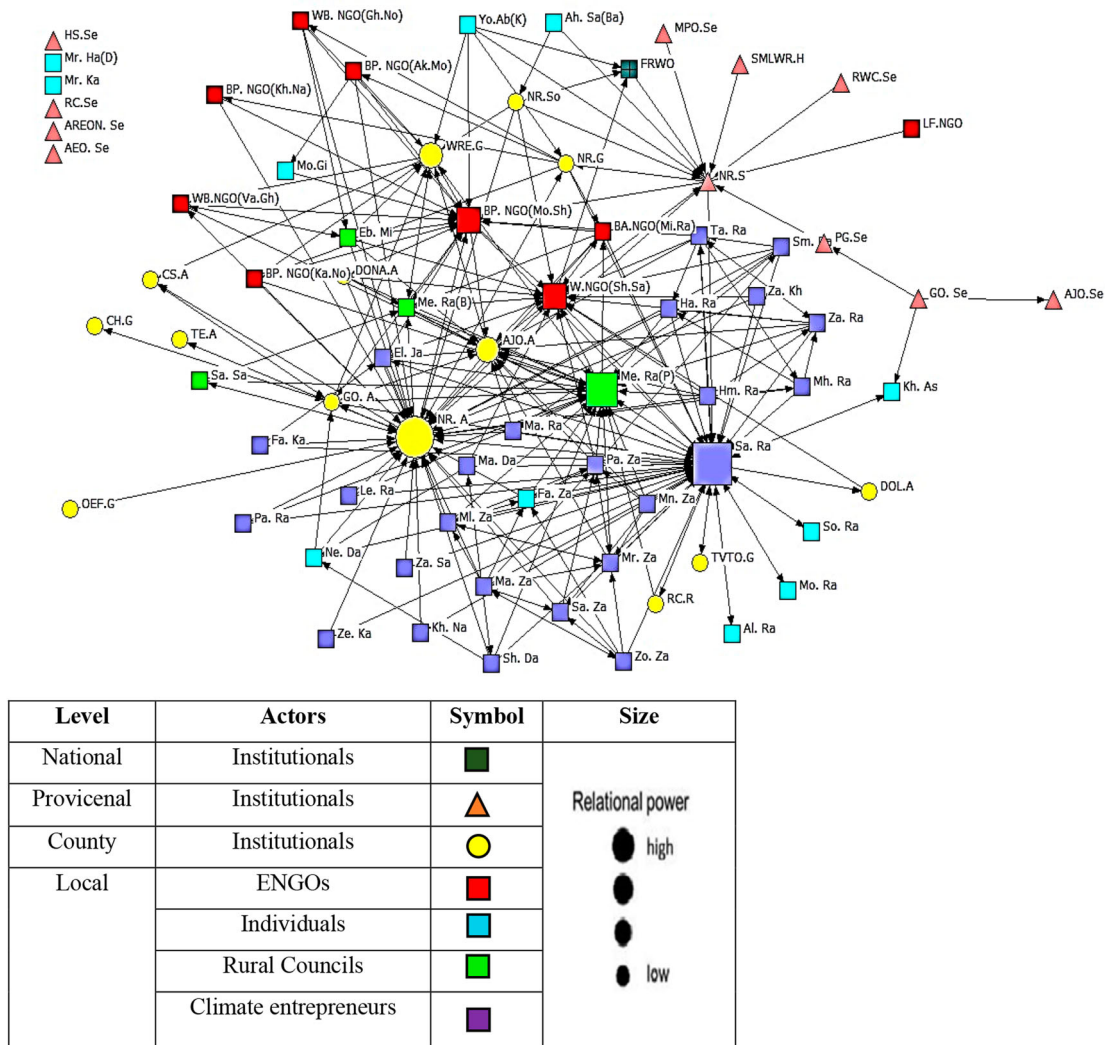


Figure 2. Network relations model of diverse and multilevel Iranian environmental actors in PGS. Source: Research findings.

3.2. Behavioral typology of actors in the network

As Figure 3 shows, PGS is based on different topologies (often star and non-equilateral triangles) that involve links between public and private entities and independent actors (heterogeneous actors).

In Figure 3, the special actors are separated by a mouse sign. In this form, the influential actors are identified with a larger and bolder form. Increasing the degree of color and size represents more communication power and higher impact. Here, NR. A is a mediator actor that connects a wide range of key players in the governance network and facilitates knowledge exchange. SA. RA is another active actor who is the source of network expansion. The communication development of this node can be seen by creating a star topology in section b, as shown in Figure 3. The actor, as a hub, has become a channel for transmitting information to the entire network in the horizontal (inside the surface) and vertical (between the levels) paths. SA. RA has a position in the center of the star network with maximum autonomy. By establishing connections with other key factors such as NR. An and NR. S (representing different levels and institutional divisions), the actor has successfully formed a robust and intricate network

comprising various actors involved in environmental governance. This multilayered network enables effective collaboration and coordination among diverse stakeholders, contributing to improved environmental management and decision-making processes. The formed communication triangle includes the relationship between the climate entrepreneurs at the microlevel (SA. RA) with a county level government institution (NR. A) and ENGOS at the microlevel (W. NGO) (Section c in Figure 3). Other triangles can also be seen here. In addition, the radial behavior of some actors (e.g. NR. S and GO. A which are the governmental actors at the provincial and county levels) is not limited to the level of a particular effect. This indicates the presence of actors with the appropriate ability to expand communication and flexible interaction in the governance network of this study.

3.3. Status of governance structure

The governance structure in this study was evaluated based on the indices of Density, Centralization, Components, Fragmentation, Avg Distance, SD distance, Diameter, Breadth, and Com-pactness. Table 1 shows the analysis of these indicators.

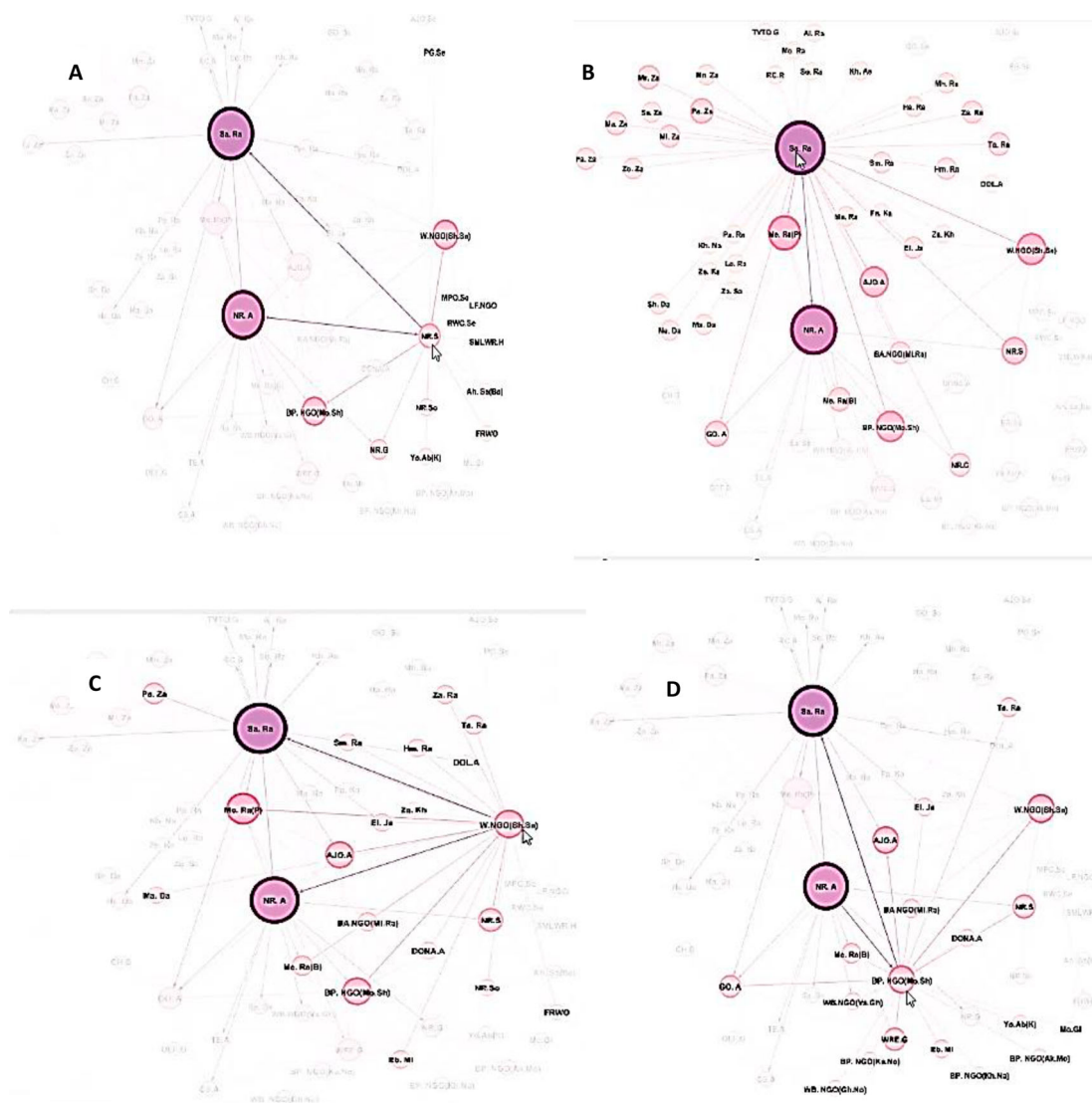


Figure 3. The results of the survey of star and triangular networks in the studied area. In this figure, larger and bolder sizes indicate greater communication power for those actors. The mouse pointer is placed next to the action that is the focus of creating a typology. (A): Triangular typology formed based on two institutional actors (at the provincial and county level) and a local actor; (B): Star typology based on a local actor; (C): Triangular typology formed on the basis of an environmental NGO; (D): Star typology formed on the basis of an environmental NGO. Source: Research findings.

The density index in the governance network was 0.06, which indicates the low density of binary relations between the actors (less than one-fifth of the possible relations have been achieved). This also indicates a low level of social capital in the governance network. In fact, it is clear that increased coordination in the field of entrepreneurship has not necessarily led to synergistic links between government actors and non-governmental initiatives in a way that ensures the effective achievement of environmental goals with high coherence. The average distance, which indicates the duration of information dissemination in the network, was 3.35 steps in our study. To reach the actors in the entrepreneurial network, the governance system faced a slow flow of information (diameter = 8). Diameter indicates the longest path of information flow

between the farthest actors of the governance network (In this study, network is actually the distance between local and national actors).

The transitivity index, which is another important indicator in answering the most basic questions of social structure with respect to the triad, states the average value of 0.42 (0.4–0.6) for the actors in the governance network. This triad arrangement is important in developing larger ties and fundamental types of social governance. As for the reciprocity index, the status of nodes is evaluated with the number 0.45 (average). The fragmentation index, which indicates the share of pairs of nodes that cannot reach each other, is very low and close to zero. In this sense, the governance network is not disconnected. The dispersion of some actors in the network,

Table 1. Results of the analysis of indicators representing the governance structure of climate entrepreneurs in Iran.

Index	Centralization	Transitivity	Hybrid Reciprocity	Density	Fragmentation	Avg Distance	Diameter	Compactness
Result	0.532	0.42	0.45	0.06	0.15	3.35	8	0.211

Source: Research findings.

Table 2. Result of the degree, in-degree, and out-degree centrality indices of the climate actors network along with a comparison of the E-I index and the approach inferred from each individual in PGS.

Actors	Degree Centrality Index	In-Degree Centrality Index	Out-Degree Centrality Index	Out-Degree Centrality Index	E-I Index	Actor approach
Sa. Ra	57	43	14	14	-0.509	Pusher (High internal & High external)
NR. A	52	40	12	12	-0.538	Pioneer (High internal & Low external)
Me. Ra (P)	28	22	6	6	-0.571	Internal
W. NGO (Sh. Sa)	23	18	5	5	-0.565	Internal
AJO. A	22	17	5	5	-0.545	Internal
BP. NGO (MO, Sh)	22	16	6	6	-0.455	Internal
NR. S	16	11	5	5	-0.375	Internal
WRE. G	16	10	6	6	-0.250	Internal
GO. A	14	8	6	6	-0.143	Internal
Pa. Za	13	5	8	8	0.231	External
Me. Ra (B)	11	6	5	5	-0.091	Internal
Mr. Za	11	5	6	6	0.091	External
Ta. Ra	10	3	7	7	0.400	External
Ma. Za	10	2	8	8	0.600	External
Ml. Za, Za. Ra, Ba. NGO (Mi. Ra)	9	3	6	6	0.333	External
Fa. Za	8	5	3	3	-0.250	Internal
El. Ja, Eb. Mi(K)	8	2	6	6	0.500	External
Hm. Ra	8	0	8	8	1.000	Symbolic leader at the local level (Low internal & High external)
WB. NGO (Va. Am)	7	3	4	4	0.143	External

especially those who do not have access to each other, hinders the full coherence and integrity of the governance network. It is necessary to pay attention to the development of interconnected and triple connections in order to finally improve the low network density. Here, the evaluation of the network continuity status, in terms of structure and based on multiple measurements, indicates its average status. The current compactness ratio is 0.2, which indicates that it is low and needs to be improved.

3.4. Comparing the behavior of actors in terms of power and leadership characteristics individually

To identify the actors with the highest information advantage and entrepreneurial resources, their approaches were compared using the out-degree centrality index, which measures their external influence. By analyzing this index, we were able to determine which players had the greatest capacity to exert influence outside their immediate network and access valuable external resources. This information is crucial for understanding the dynamics of the network and identifying key actors who possess significant strategic advantages in terms of information and resources. The reputation and authority of the actors and their abilities were also compared. Regarding the integration in the entrepreneurial network, Table 2 shows the four positions of the actors, which are obtained by combining internal and external ambitions from top to bottom of the actors (only core class memberships). Accordingly, the actors were divided in terms of power and leadership. The result of the study shows that an actor of a governmental institution with a protective (NR. A) and pioneering role and with the highest internal degree of centrality is an important source of structural strength and establishes himself as a structural leader. Other actors in the local sector, such as members of village councils, but not all of them (e.g. Me. Ra (P)) have been able to demonstrate structural leadership. A member of the climate entrepreneurs (Sa. Ra) is known as a powerful and influential woman who acts as a pioneer.

The success in carrying out progressive leadership activities can be attributed to the extensive interaction among several specific actors with more prominent cooperation of actors at the city and local levels. As a pusher actor, Sa. Ra, with the help of other local actors (e.g. HM. RA and Mn. Za), has played a vital role in establishing intermediate vertical intermediate connections. Interacting with local ENGOs (e.g. W. NGO or BP. NGO (MO. Sh) and WB. NGO), which have the maximum number of entry-level and indegree centrality in local groups, facilitates horizontal growth at the local level. This pusher also cleverly used influential people in local councils such as Me. RA and SA. SA. Interaction with institutions (e.g. AJO. A) at the county level and at the provincial level (NR. S actor), the development of entrepreneurial ideas has been carried out in micro-networks with the effective role of such activists.

3.5. Comparing the performance of governance units in terms of power and communication characteristics

Since each unit of PGS interacts with other units independently, a reasonable way to understand the performance of units in the governance network is to evaluate and describe the characteristics of the centrality indicators of the units together. The effective decision-making centers or units in the PGS were five centers, including government institutions, ENGOs, individuals, village council members, and climate entrepreneurs (77 actors in total). Figure 4 indicates a box plot diagram of the status of different units in terms of three types of centrality performance. Included in the degree centrality index are the in-degree of centrality index, which measures the level of authority and reputation of players within each unit, and the out-degree centrality index (representing level reflects the social influence of the actors in each unit). In addition to the E-I index, which compares the overall position of all actors in the governance network with the individual approach of each unit in the network, we also considered the difference between the outgoing communications of the unit's members and the total linkages of that actor. This comparison helps us assess the level of influence and communication

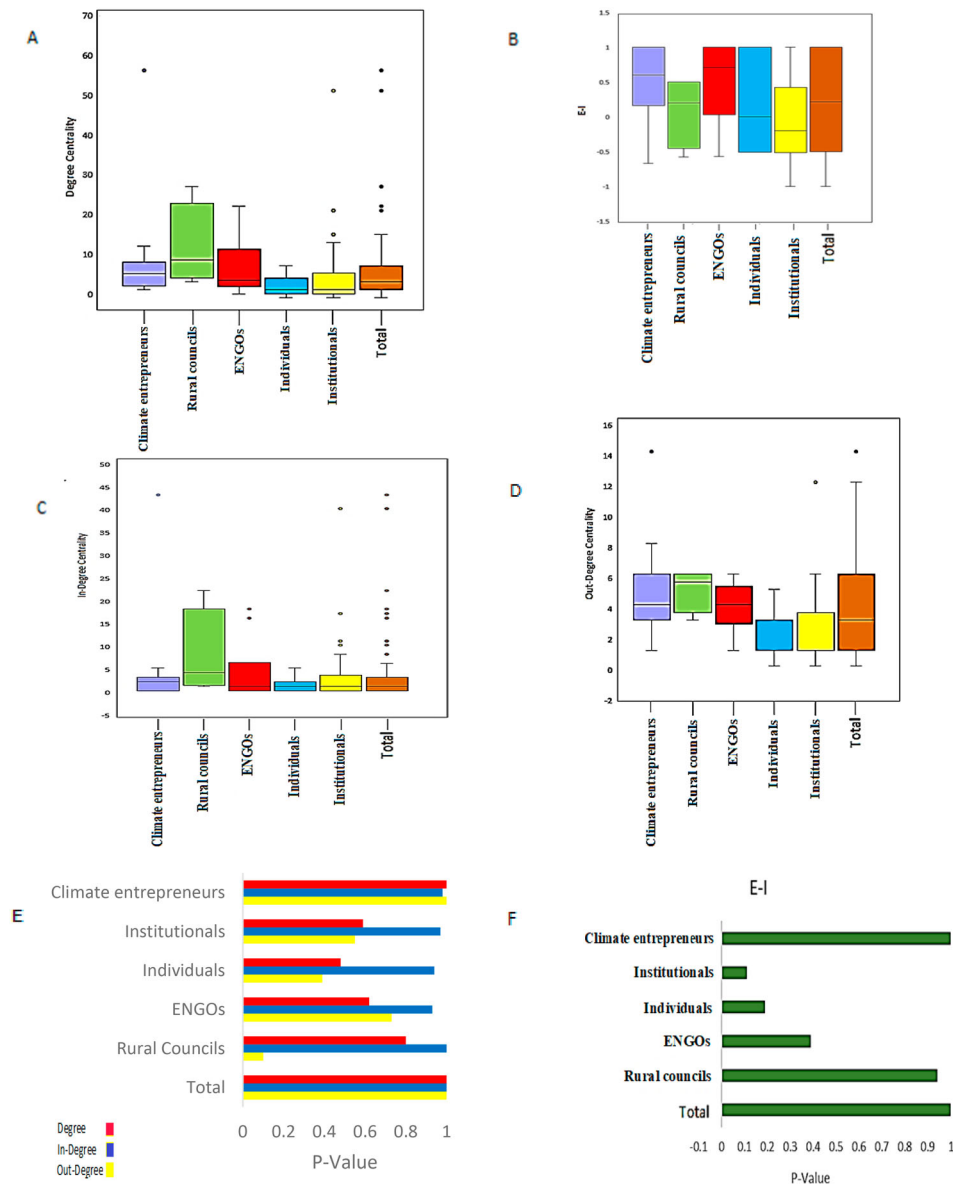


Figure 4. Network degree centrality characteristics of different types of actors in PGS. (A) Degree centrality. (B) E-I Index. (C) In-Degree centrality. (D) Out-Degree centrality. (E) & (F) *P*-values of degree centralities and E-I index of actors comparing individually and with total (all actors collaborating in PGS).

effectiveness of each unit within the network. By examining this index, we gain insights into how each actor's approach aligns with the collective goals and strategies of the governance network, providing a comprehensive understanding of their contribution to the overall dynamics of the network. The box plots allow different groups to be compared at the same time.

The results show that different actors in PGS are close to each other in terms of performance of the in-degree centrality index. The performance of the degree centrality and out-degree centrality indices, on the other hand, differs and may be classified into high, medium, and low effect ranges. In other words, there is a slight difference in terms of the degree of centrality in the four units of institutions, individuals, climate entrepreneurs, and ENGOS. While the unit of village council members (known as Dehyar) in this category (creating the most local and intragroup communication) has demonstrated a greater performance (Captions 'A', 'C', and 'E' in Figure 4), it is not as successful as the system of governance

(total status). Even 50% of the performers in this unit do better than the center of the unit. This shows that the rural council unit outperforms both the middle of all other units and the center of the total (Caption 'C' in Figure 4).

The most obvious point is that the highest rate of the change of the in-degree centrality index is seen in the unit of the rural council (between 2 and 22). However, in the performance of the out-degree centrality index (access to external resources), it is clear that the governance system (total status) is not gender-sensitive (section D in Figure 4). In the E-I index (Caption 'B' in Figure 4), the performance of units is different and is located between -1 and 1 .

3.6. Comparing the performance of actors individually in the governance system in terms of mediation and access to information

In the PGS of climate entrepreneurs, the traditional institutional actors such as NR. A, GO. A, and AJO. A show

Table 3. Betweenness and closeness centrality of PGS of climate entrepreneurs in Iran.

Level	Actors	Betweenness Centrality Index	Closeness Centrality Index	Status
Local	Sa. Ra	86.818	0.612	High Betweenness High Closeness
	BP. NGO (Mo. Sh)	17.880	0.492	Moderate Closeness
	W. NGO (Sh. Sa)	14.420	0.508	Moderate Closeness
	Me. Ra (P)	12.131	0.508	Moderate Closeness
	WB. NGO (Va. Am)	6.909	0.434	Moderate Closeness
	Pa. Za	5.147	0.446	Moderate Closeness
	Sm. Ra	3.652	0.521	Moderate Closeness
	Ta. Ra	2.985	0.485	Moderate Closeness
	Me. Ra (B)	2.247	0.5	Moderate Closeness
	Kh. As (L)	1.933	0.384	Low Closeness
County	NR. A	69.026	0.612	High Betweenness & High Closeness
	GO. A	14.914	0.514	Moderate Closeness
	AJO. A	6.494	0.526	Moderate Closeness
	WRE. G	5.686	0.428	Moderate Closeness
	NR. G	1.589	0.483	Moderate Closeness
Provincial	NR. S	22.725	0.517	Moderate Closeness
	PG. S	1.067	0.348	Low Closeness
National	MPO. S, SMLWR. H, GO. Se, RWC. S	0.000	0.348	Low Closeness
	FRWO	15.203	0.348	Low Closeness

their important effects (Table 3). However, polycentrism in the system is described as rising non-governmental entities, such as private NGOs (referred to in our network as BP. NGO, W. NGO, or WB. NGO). As shown in Table 3, the betweenness centrality of most non-governmental actors at the local level has been an attractive complement to traditional roles at the county and provincial levels. Table 3 shows only the actors in the core class with the highest score in each level.

At the local level, the launch of non-governmental actions is evident in the network. Across the social network, NR. A is a government intermediary that accelerates the development of PGS communications with capable entrepreneurial and pusher actors from the microlevel (such as SA. RA) with the highest centrality degree.

SA. RA is recognized as a high-level champion for mobilizing climate entrepreneurship by non-governmental and sub-national actors. This is because SA. RA is the actor who connects the largest number of network actors for faster communication (with fewer intermediaries). Indeed, the climate entrepreneurs' extremely strategic placement has created it with the largest percentage of information has a very high potential to assist the spread of entrepreneurial communication. Similarly, the NR. S (i.e. upstream government institution of NR. A) in the province has the third rank of total centrality, which confirms its high capability in expanding entrepreneurship.

The results show that different actors can be found, regardless of whether they are at a certain level or belonging to a specific institution, in order to accelerate access to entrepreneurial resources and information.

3.7. Comparing the performance of governance units in terms of mediation and access to information

Figure 5 shows the box plot diagram of the situation of different actors in terms of two types of centrality functions, including the betweenness centrality index and the closeness centrality index, in comparison with the governance system (total status). The comparisons show that entrepreneurs and

members of rural councils have a higher centrality performance. This means that they have the ability to transmit information in the shortest time, compared to other units in the governance network. The lowest performance is related to independents and government institutions in the closeness centrality index (Caption 'A' and 'C' in Figure 5). However, regarding the performance of the betweenness centrality index (being a broker), we can say that the difference between the units is very small. However, the performance of non-governmental actors is slightly better than that of governmental and individual actors.

3.8. Actors' relational profiles

The two primary categories of controlling actors may be differentiated based on the two parameters of betweenness centrality and proximity (Figure 6). The institutional actors, both governmental and non-governmental, operate at the county, provincial, and national levels and have an influence at the local level (private actors include ENGOS, independents, members of rural councils, and climate entrepreneurs). These two types of actors behave similarly in general. In terms of creating intermediate links, the accumulation of their actors is in the lower 1/5 of the box plot. Moreover, in terms of the minimum access time to resources, a cumulation of both groups of actors is observed in the distance between 3 and 6 points. The highest and lowest scores in this index are 6 (belonging to the climate entrepreneurs) and close to zero (independent individuals), respectively. The climate entrepreneurs, however, have the highest degree of betweenness centrality (more than 80), while a large concentration of persons with extremely low degrees below 0.5 and almost zero is seen in governmental organizations.

4. Discussion

This study is a structural and functional evaluation that identifies multilevel, diverse, and heterogeneous actors. Then it demonstrates how the effectiveness of individual actors and

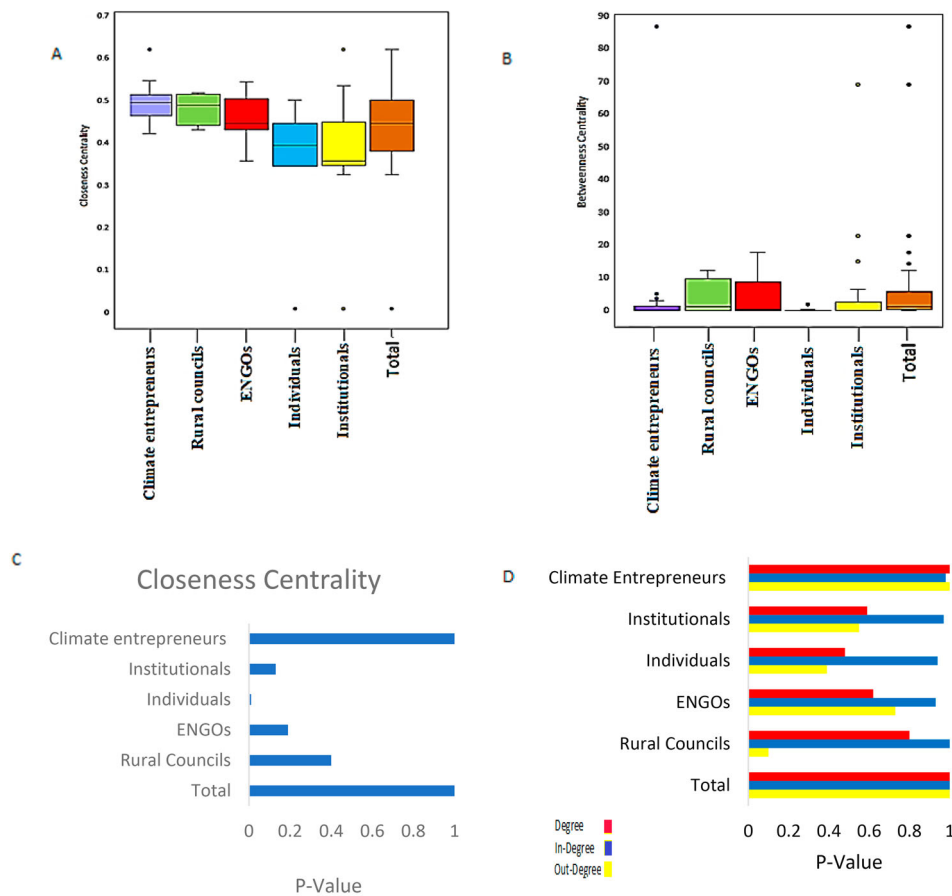


Figure 5. Network centrality characteristics of different types of actors in PGS. (A) Closeness centrality, (B) Betweenness centrality, (C) & (D) P-values of comparing degree centrality of actors individually and together (all actors collaborating in PGS).

eventually the performance of the entire network are influenced by the network's cohesiveness, position, leadership, and power of the unit.

4.1. Stability and coherence of the governance structure

The creation of a star topology in the PGS of Iranian climate entrepreneurs by a number of highly centralized actors has led to the connection of key actors to the entrepreneurial hubs of the governmental and non-governmental sectors. It has also enabled faster and more accurate information transfer at different national, middle, and local microlevels. In this study, the assessment showed that the existence of a star topology has been useful for the development of PGS. As Van Asselt (2014) points out, the governance network is influenced by governing units which affect the performance of other units. For the following three reasons, polycentric units at different levels were recognized as valuable assets for the Iranian climate entrepreneurs: (1) As Boasson and Huitema (2017) point out, they have created more entrepreneurial opportunities. (2) They have also increased success by increasing the volume and variety of entrepreneurial relationships (Jordan et al., 2018). (3) These units have provided the creation of innovative business models by focusing on positive features, especially high adaptation to climate change (Klein et al., 2019). Therefore, climate entrepreneurs are considered key players and

centers that accelerate social and environmental sustainability. This is because climate entrepreneurs can significantly reduce the negative effects on the environment and society by changing the communication behavior of institutions, creating economic values, and also presenting and absorbing network values (Palm et al., 2020). At the same time, along with the multilevel development of governance actors, the coherence of the overall governance structure was also considered important. Among the positive outlook factors for the greater sustainability of the PGS under study were the high reciprocity and the transitivity of network relations influenced by climate entrepreneurs, especially the role of women. In particular, the connected and non-disconnected network structure confirms that it has the necessary potential to realize all the really basic forms of social relations, and the realization of a more stable vision and greater coherence in it is not out of reach. Thus, as Muller and Peres (2019) emphasize, the growth of innovation centers in network governance is shaped by the structure of the network and its coherence. In other words, the structure of the social network affects the performance of the entrepreneurship and innovation market.

4.2. Position and performance of units in developing knowledge

This study complements prior research that highlights the value of intermediary position actors who may facilitate

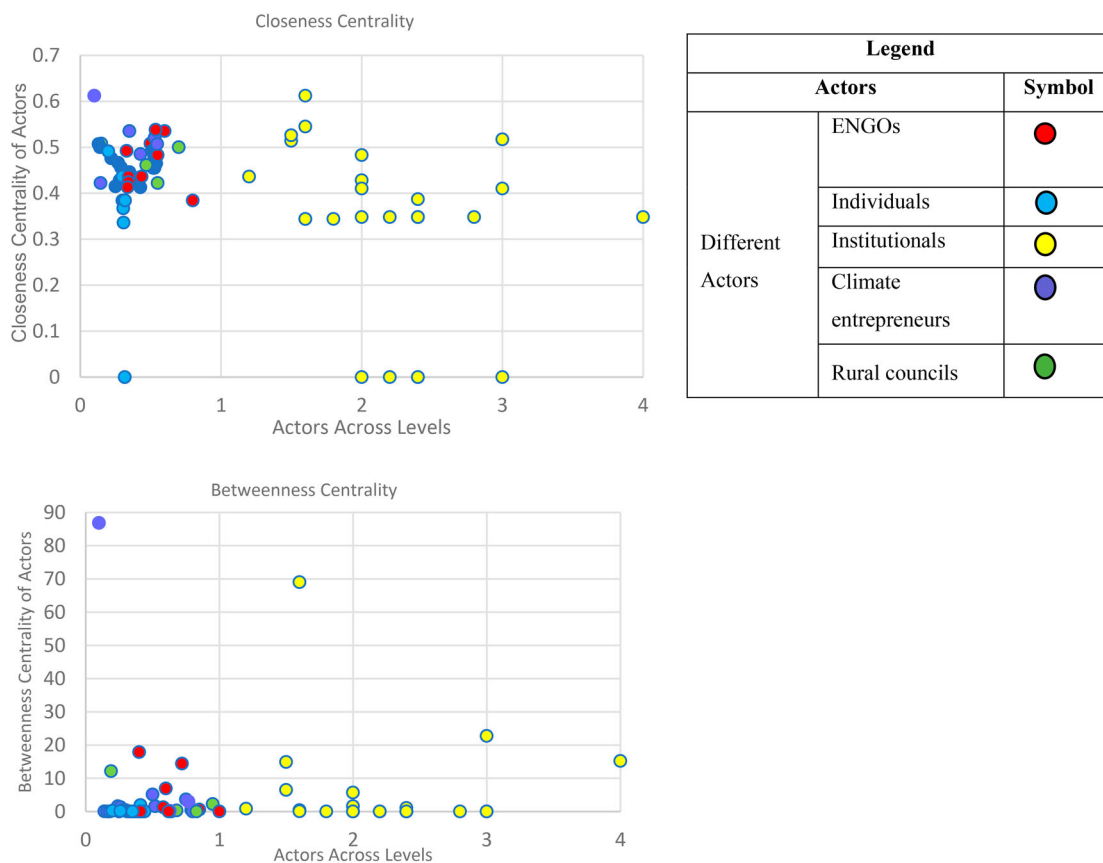


Figure 6. Weighted scatterplot representing the centrality scores (closeness centrality, betweenness centrality, across levels) of actors in the PGS of climate entrepreneurs.

linkages across otherwise disjointed [network] parts of the polycentric governing units (Koontz, 2021; Scott & Thomas, 2017). This is because these situations provide more sources of information that may include learning about financing opportunities or existing technical data (Scott & Thomas, 2017). Brokerage positions lend power that actors and units can leverage (Ingold & Leifeld, 2016), for instance, to influence the direction and outputs of PGS (Scott & Thomas, 2017). The results of this study are in line with those of Study Koontz (2021) who confirms that units' collaboration in climate governance leads to access to entrepreneurial sciences horizontally, and that vertical transfer relies more on knowledge brokers. Comparing the behavior of two governmental and non-governmental actors (regardless of the comparison of the scores of the actors in their subset) shows that in establishing intermediate links and in the minimum time of access to resources, it has the upper hand (superiority) with non-governmental actors. In the brokerage index, there is no significant difference between the scores of all institutional and non-institutional actors.

The results of the betweenness index analysis showed that a very important factor in facilitating and increasing climate entrepreneurial activity is the position of unique actors in receiving and disseminating knowledge (Kruse et al., 2019). This position leads to the effective transfer of knowledge at the appropriate speed at all levels of the network (Amorós et al., 2019). The results of this study clearly showed that the communication ability of female actors at the microlevel in

the initial form of climate entrepreneurs has had a significant impact on expanding PGS and reducing the barriers facing them (Naderi et al., 2020).

4.3. The performance of the governing actors in terms of the leadership role of the system

In this study, we found that leadership and power roles are related but not the same. Powerful (structural) actors may not actually use it to exercise (structural) leadership, which we confirm here (Lieverink & Wurzel, 2017). This was primarily relevant in this study to some government actors (e.g. the NR. A) who were competent to enforce safeguards. Other actors, such as ENGOs as non-governmental institutions, do not have any economic power of their own. They derive structural power from the amount of communication, popular support, and interactions they have established with the general public (Jordan et al., 2018), which is in fact another form of structural power. These NGOs have moved faster than traditional institutions in communication activities and have often overcome many deadlocks in entrepreneurship development (Bourceret et al., 2021). For example, water transfer projects or the development of by-products (e.g. production and operation of medicinal plants or production of organic products) are among these cases. Therefore, the higher power of control and greater diversity of information sources by the entrepreneurial leadership have led to the expansion of governance (Sovacool & Van de Graaf, 2018).

The reasons for the expansion of the rule of climate governance in Iran are influenced by two important factors: (1) It is mainly affected by the efforts of entrepreneurial leadership and cognitive leadership of female actors at the local level. At the local level, this work is increasingly shaped by injecting horizontal social capital into NGOs or powerful and influential individuals providing local-level funding. (2) Using the mediating role of stakeholders at the middle level of government. The key role of the government here is to create favorable conditions for local initiatives (Jänicke, 2017) and to provide effective sources of financing in terms of both supply and demand (Kou et al., 2020). Another point in our findings that is worth mentioning is that influential institutional actors in the governance process (e.g. the NR. A) are located at the county level, not at the national level. As an important source for the structural leadership of environmental activities in PGS, these traditional actors have been able to create strategic links among different types of actors to achieve environmental goals. The findings of this study explicitly refute the results of Ishtiaque et al. (2021) because organizational actors located at the county and provincial levels are more dynamic and effective than national actors and because they are the most important sources for the structural leadership of environmental activities in PGS.

4.4. The performance of governance units in terms of the role of social power and leadership in the system

Regarding the power of internal cohesion, the evaluation of the performance of the units (apart from the study of the key actors) showed that there is no significant difference between a large number of actors in terms of popularity (Kharanagh et al., 2020) and that there are only a few key actors who have high leadership power. In the performance of the output degree centrality index, the possibility of a performance demarcation between units was obtained. Considering the index of out-degree centrality (social influence and access to external resources), it is noteworthy that the system of governance (a large network consisting of all units) showed a superior and higher effect, which was influenced by the higher performance of non-governmental units, especially climatic entrepreneurs. Meanwhile, in accordance with the findings of Nabiafjadi, Sharifzadeh, and Ahmadvand (2021), the findings of this study revealed that a little variation in the in-degree and out-degree centralities of the units within PGS promotes the connection of active/interactive actors and the formation of bilateral linkages. Institutional stakeholders tend to take a more intragroup approach in the system performance outcome index, which is typical of the E-I index. However, the impact of the performance of institutional actors has not led to a change in the extraversion of the governance system. In other words, the positive effect of other units has led to a systemic approach to developing connections with members outside the network and to greater access to external resources (with higher extra-group social capital). Therefore, it is inferred that the performance of heterogeneous units is variable, which is affected by the position of that unit and the leading power of the actors within them at different levels of governance. The findings of this study were in line with the

outcomes of Ishtiaque et al. (2021) who considered the role of individual institutional actors and their sets in shaping the process of consistent governance to be effective. However, studying institutions as the only effective actors in shaping PGS does not lead to accurate results, and it is necessary to test a wide range of diverse and heterogeneous units for a better understanding. Considering that each unit in a polycentric system makes significant independent efforts to create norms and standards in a given region (Rayner & Jordan, 2013).

This study has some limitations. One of the main limitations of the network governance analysis was the identification and need to access numerous and diverse actors involved in interviews. Especially with the outbreak of COVID-19, many trips to cities and villages, as well as the presence of many office workers, were restricted.

5. Conclusion

The path to achieving polycentric climate governance is a multilevel and multilayer process that requires the collaboration of ENGOs, institutions, individuals, rural councils, and especially climate entrepreneurs and many other units as decision centers to develop specialized knowledge and provide funding. This study showed that understanding the dynamics of power and leadership characteristics (network features) consists of the coexistence of many self-organized decision-making centers that are formally independent at different levels. These centers operate under a set of comprehensive rules (as the basis of polycentric systems) and can accelerate the development and stability of PGS. Quantitative and qualitative improvement of actors' performance in terms of macrosocial network indices such as reciprocity, transitivity, density, and compactness ratio has a direct effect on increasing stability. The adequate level of stability by a number of highly centered actors facilitates the connection of decision centers among different levels of PGS. The lack of coherence and stability of the collaboration network (to a sufficient extent) along with the lack of intermediary actors are the main obstacles to the formation of a multicentered network. In terms of quantity and quality of network communications, micro (local), intermediate (county and provincial), and national levels showed the highest to lowest performance, respectively, in terms of influential actors in PGS. The leadership power of key actors is also recognized to have a very effective role in the stability and development of PGS. This social presence, influenced by the high brokering performance, has led to the emergence of entrepreneurial talent and provides access to specialized education.

The findings of this study also showed that a wide range of governmental and non-governmental actors are able to develop network communication as a leader at different levels. This requires purposeful communication efforts of leading actors to create appropriate triangular and star topology forms. Entrepreneurial leadership opportunities in PGS also allow actors of limited size and capacity to exercise leadership beyond their borders and increase cooperation links with coherence. Powerful pioneers were also found to be very effective in improving performance and environmental sustainability by injecting social capital. The impacts of ENGOs and

climate entrepreneurs on governance expansion and its performance indicators were positive and significant because these actors can put pressure on potential entrepreneurs and develop new entrepreneurial ideas or income-generating knowledge.

5.1. Policy recommendations

This study proposes the collaboration of international policy-makers based on the building of a triangular core to accelerate the development of polycentric climate governance. The first aspect is to use the capacity of informal markets by focusing on the power of NGOs and key leading actors in local communities (especially focusing on climate entrepreneur actors). The other two sides of its auxiliary and motor arms are the two components of immediate and rapid access of individuals (institutions) to the specialized knowledge of entrepreneurship from public or private centers and with the support of a diverse group of financial sponsors such as rural councils. Here, the functional role of multilevel leaders, who are known for special traits such as social influence and entrepreneurship, is important in connecting groups and aligning demands. This requires planning and revising communication skills and work practices, including building relationships with key individuals and public and private institutions and promoting informal and shadow networks for the development of social relations, to be used flexibly and adaptively when needed. Finally, political, institutional, and local entrepreneurship can be strengthened in PGS by programming to turn into unexpected and facilitating opportunities and 'windows' that quickly become open and active, with the ability to mobilize resources quickly and flexibly in the broader field of climate change.

Therefore, this study confirms that polycentric climate governance is very important in knowledge transfer, learning development, and collaboration communication because it has been able to avoid formal requirements. In other words, it leads to a horizontal and vertical increase of units, including entrepreneurs on larger geographical scales. This paper recommends a polycentric order to climate policy-makers that combines the independence of decision-making levels and multilateral interaction between leadership powers as one of the most important facilitating factors of this approach that are not merely entrepreneurs but have a strong ability to link social capital. The primary goal of PGS is to create a network for environmental protection through increasing financial connections, altering the flow of information, and redistributing power between local and federal levels. In previous studies, the performance of formal and informal institutions together in polycentric governance has rarely been shown. Most governance system practices in previous studies included government interventions. In fact, the method of polycentric governance can be understood based on the performance of society and the market. This study specifically covered the need for research on the functional impact of governance sub-centers on the final view of governance as a whole and its functional output. This research gap was revealed by studying all informal and formal institutions together at several levels using large amounts of data. At the same time, this study helped to strengthen the intellectual foundations

of this approach by combining the assessment of structural stability and the dynamic aspects of power, leadership, and social learning. Performance comparison showed that public administration in polycentric governance networks cannot fulfill leadership criteria as much as private actors can. Identifying and planning local climate entrepreneurs capable of making the polycentric environmental protection network more stable and active. The longest waiting time to access new information is caused by limited and unestablished network relationships between levels. In order to solve this lack of governance, it is suggested to form committees centered on PGS at the county and provincial levels from central actors who have a higher mediating function and to update the required information continuously.

Knowing their performance and controlling them in a world where PGS is evolving is still a critical challenge. Considering the need for more studies in the overall understanding of the polycentric climate governance system, the future line of research can be the answer to the question of how PGS can sustainably affect the network structure and performance of decision centers over a long period of time. This is because actors are not fixed and society is dynamic and constantly changing. There are other questions that have not yet been definitively answered. For example, how does unit performance affect network structure and performance over a longer time horizon? Does PGS provide proper performance for a long period of time due to changes in structures? How this multidimensional collaboration is established at the global level?

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Appendices

Appendix 1. Network Analysis questionnaire of polycentric governance system of environment in Iran

Q1: Which individuals, non-governmental institutions or governmental institutions have been influenced in your decisions in the various stages of rangeland management, environmental challenge or natural resources management? Make a list of these people or groups.

Name of institutions (Public or private)	Name of Individuals
1	1
2	2
3	3
4	4
5	5

Q2: Are there any specific places or events you participated in? (e.g. Participatory rangeland rehabilitation, empowerment and capacity building in local communities, entrepreneurial activities, public dredging operations of water resources, joint exploitation of by-products, public response to environmental pollution) etc.)

If yes, name the type of activity and the name of the department or institution or any governmental or non-governmental person you worked with.

Name of the institutions or private or public persons involved in the activity	Type of Activity
1	1
2	2
3	3
4	4
5	5

Q3: Based on the nominations respondents gave to these questions, we asked respondents a series of follow-up 'name interpreter' questions. These questions allowed us to gather more detailed information on the nature of the actor (s), and they included the following:

Q3-1: How frequently do you interact with this person or group? [] very rarely [] a few times/year [] monthly [] weekly [] daily (Please note: We inputted the above data as 1 = very rarely ... 5 = daily)

Q3-2: How would you define your relationship to them? Select as many as apply: [] colleague [] family [] friend [] employe [] neighbor [] other.

Appendix 2. Description and Range of network indices to evaluate the structure and and compare of the polycentric governance actors

Network Indices	Description and Range of index
Density	The density is an important network-level measure, which is able to explain the general level of connectedness in a network. The relationship between density and structural cohesion is built on the same basis because the structural cohesion index includes links that lead to the most basic communications and eliminating them can cut the communication (Islami, 2021). Increasing indices like the density index, it is expected that social capital is strengthened, and social resilience to problems of climate restrictions that have affected beneficiaries is also increased (Islami, 2021). Density can have a value ranging from 0, if all the ties are absent, to 1, if all the possible ties are present (Islami, 2021).
Centralization	A centralization index aims at capturing to what extent a given property is unevenly distributed among network nodes and is used to refer to particular properties of the network structure as a whole (Piccardi & Tajoli, 2018). Decentralized networks are those having low diversity in the number of actors' links (Islami, 2021). The score range of this index can also be calculated between 0 minimum to 1 maximum (Varini et al., 2020).
Transitivity	A property very important in social networks, and to a lesser degree in other networks, is the transitivity index. It refers to the extent to which the relation that relates two actors in a network that are connected by an edge is transitive (Chae et al., 2020). $T = 1$ implies perfect transitivity, i.e. a network whose components are all cliques which is very rare in real networks. $T = 0$ implied no closed path of length two, which happens for various topologies, such as a tree or a square lattice.
Hybrid Reciprocity	Reciprocity represents the proportion of reciprocal relationships within a network (Giesbers et al., 2019).
Fragmentation	Fragmentation refers to the proportion of pairs of actors that cannot reach each other. If fragmentation is >0 , the network is disconnected (Harvey et al., 2020).
Avg Distance	Shortest distance – a minimum number of steps that the actors are away from each other in a network and in weighting networks the tie weights shall be taken under consideration (Gogaladze et al., 2020).
Diameter	Diameter measures the distance between the two nodes furthest apart in the network, or the largest geodesic distance (The longest path of the information flow between the furthest actors in the network (Lee et al., 2019)).
Compactness	The cohesion-based distance index (Distance-based cohesion) is the mean of all the reciprocal distances – range 0–1; larger values indicate greater cohesiveness (Nicolosi et al., 2018).
Degree centrality	The degree centrality index is defined as the number of actors that are well connected to others. Social researchers measure the role of an actor using degrees (Islami, 2021). In fact, the actor who has a higher degree of centrality can assume the leadership role (Larrañeta et al., 2020). Centrality indices are a proper tool to represent the power position of actors who increases the knowledge it receives and their potential learning having consequences for the development of critical skills and capabilities and ultimately performance. (Larrañeta et al., 2020). The degree of centrality is divided into in-degree centrality and out-degree centrality. The in-degree centrality refers to the number of incoming connections from other actors, and the out-degree centrality is the number of outgoing connections from an actor (Larrañeta et al., 2020). A high in-degree centrality indicates the popularity of the node and a high out-degree centrality implies the greater influence and effectiveness of the actor (Larrañeta et al., 2020).
E-I	E-I index is the number of ties external to the groups minus the number of ties that are internal to the group divided by the total number of ties (to measure homophily among the groups) (Ogada et al., 2017). The E-I index is important in calculating the relationship between

(Continued)

Continued.

Network Indices	Description and Range of index
	members of a given group and the amount of interaction that one has with stakeholders external and internal to one's group (Kharanagh et al., 2020). A score can range from 1 to -1 The index is also calculated for each group and for each individual actor. A score of -1 for the E-I index means that a stakeholder interacts only with members of its own group, thus indicating homophilous relationships (Kharanagh et al., 2020). On the other hand, an index of +1 shows that a stakeholder interacts with others external to one's own group, which translates to heterophilous ties (Ogada et al., 2017).
Betweenness centrality	Betweenness centrality is used to measure the centrality in a network based on the shortest path theory vertices on shortest path always have higher betweenness centrality than others (De Nooy et al., 2018). Actors with a high level of betweenness centrality act as relays in the ecosystem communication control (Neumeyer & Santos, 2018). Betweenness centrality quantifies how many times an actor acts as a bridge along the shortest path between the two other actors (Kharanagh et al., 2020). Using this index, one can identify the actors that can play the role of a connector (broker or mediator) between separate sectors and multi-level environmental governance networks (Hamilton et al., 2020).
Closeness centrality	It refers to the shortest path between the deployed actors. Therefore, the closest actors, have highest visibility in a network (De Nooy et al., 2018). For finding the individuals who are best placed to influence the entire network most quickly (Ianni et al., 2021). Closeness centrality can help find good 'broadcasters', but in a highly-connected network, you will often find all actors have a similar score (Ianni et al., 2021).

Appendix 3. Full and abbreviated names of actors and their role and level of activity in the governance of climate entrepreneurs in Iran Source: From the research results

Full name of Actors (Abbreviation name)	Different Actors and their kinds	Levels
Forest Range and Watershed Management Organization (FRWO)	Institutional/Protective	National
Department of Natural Resources and Watershed Management of Semnan Province (NR. S)	Protective/Institutional	Province
Regional Water Company of Semnan Province (RWC.Se)		
Sustainable Management of Land and Water Resources Hablehroud of Semnan Province (SMLWR.Se)		
Agriculture Jihad Organization of Semnan Province (AJO.Se)	Developing/	
Provincial Government of Semnan Province (PG. S)	Institutional	
Managing and Planning Organization of Semnan Province (MPO.Se)		
Health Services of Semnan Province (HS. Se)		
Rural Cooperative department of Semnan Province (RC. Se)		
Governorship Organization of Semnan Province (GO.Se)		
Agricultural Research Education and Extension Organization of Semnan Province (REON. Se)	Intermediate/	
Agricultural and Natural Resources Engineering Organization of Semnan Province (AEO.Se)	Institutional	
Natural Resources of Garmsar County (NR. G)	Protective/Institutional	Counties
Natural Resources of Aradan County (NR. A)		
The Environment of Garmsar County (TE.G)		
Governorship Organization of Aradan County (GO. A)	Developing/	
Department of Agriculture Jihad Organization of Aradan County (AJO.A)	Institutional	
County Seat of Aradan County (CS. A)		
Department of Water resources engineering of Garmsar County (WRE.G)		
Rural Cooperative of Rameh(RC.R)		
Cultural Heritage of Garmsar County (CH. G)	Intermediate/	
Technical and Vocational Training Organization of Garmsar County (TVTO.G)	Institutional	
Department of Nomadic Affairs of Aradan County (DONA.A)		
Omid Entrepreneurships Fund of Garmsar County (OEF.G)		
Department of Labor of Aradan County (DOL.A)		
Women Micro Credit Fund of Farvan (WMF. NGO)	ENGOS	Local
Byproducts-Mo.Sh (BP.NGO)		
WB. NGO (Va. Am)		
WB. NGO (Gh. No)		
WB. NGO (Sh. Na)		
Nematolah Darvishi (Ne. Da) Khatoon Ashoor(Kh.As)	Mohamadreza Kalaie (Mr. Ka)	Individuals
Faramarz.Zahak (Fa. Za) Mohamad Gilvari(Mo.Gi)	Ahmad Saeedi(Ah.Sa) Yosof Abedian (Yo. Ab) Somayeh Rameh (So. Ra) Ali Rameh(AI.Ra)	
	Mohamadreza Hafezi(Mr.Ha)	
Council of Rameh Paeen- Meysam Rameh (Me.Ra(P))		Rural Councils
Council of Kohanabad- Ebrahim Mirzaie (Eb.Mi)		
Council of Rameh Bala- Meysam Rameh (Me.Ra(B))		
Council of Farvan- Saeed Saboor (Sa.Sa)		
Sakineh Rameh (Sa. Ra) Maleknaz Zahak(MI.Za) Shahin Darvishi(Sh.Da)	Sakineh Zahak (Sa. Za) Marziyeh Zahak(Mr.Za)	Climate entrepreneurs
Hajar Rameh (Ha. Ra) Parvane Zahak (Pa. Za) Zeynab Kashani (Ze. Ka)	Zahra Safaiipour (Za. Sa)	Elham Javidi (El. Ja) Hamideh Rameh(Hm.Ra)
Parvin Rameh (Pa. Ra) Kadijeh Nasir (Kh. Na) Maryam Darvish (Ma. Da)	Masoumeh Zahak (Ma. Za) Zahra Khaleghi (Za. Kh) Somayeh Rameh (Sm. Ra) tayebe Rameh (Ta. Ra) Fatemeh Karimkhani (Fa. Ka) Manijeh Zahak (Mn. Za)	Zohreh Zahak (Zo. Za) Zahra Rameh (Za. Ra) Mah Khatoon Rameh (Mh. Ra) Mahin Rameh (Ma. Ra) Leyli Rameh (Le. Ra)