



Can Social Networks Drive Adaptive Capacity? A Social Network Analysis of Carbon Sequestration Project Impacts in Rural Communities

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ABSTRACT

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Objective: This study examines the structural aspects of Social Capital (SC) in sustainable community development, focusing on four villages in Southeastern Iran participating in the International Carbon Sequestration Project (ICSP). The research aims to understand how collaboration, trust, and gender dynamics within Village Development Groups (VDGs) influence collective action and resource mobilization, key precursors to adaptive capacity in a resource-constrained socio-ecological system.

Methods: Using Social Network Analysis (SNA), data were collected through structured questionnaires administered to 268 members of traditional and mixed-gender VDGs across four villages (Chah1, Gazdez, Kasrab, and Tajmir). Illustrative participant comments were also recorded to contextualize the quantitative findings. Network metrics including density, reciprocity, transitivity, and geodesic distance were calculated to map trust and collaboration ties.

Results: Results revealed that Tajmir VDGs exhibited the highest collaboration density (70.3%) and reciprocity (over 65%), indicating strong mutual trust and resource-sharing. Mixed-gender groups in Gazdez demonstrated more balanced leadership distribution and higher satisfaction with decision-making, while traditional VDGs showed more hierarchical structures. The ICSP significantly enhanced bonding and bridging social capital, particularly empowering women's participation.

Conclusion: These findings confirm that dense, reciprocal, and inclusive social networks are foundational for community resilience and adaptive capacity. SNA proves an effective diagnostic tool for identifying network strengths and weaknesses. The study offers practical implications for policymakers, recommending gender-inclusive participatory structures and sustained capacity-building to strengthen social capital as a driver of sustainable rural development in arid regions.

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Introduction

Sustainable development in arid and resource-constrained regions presents one of the most pressing challenges of the twenty-first century. Communities in these areas must navigate acute environmental pressures, socioeconomic marginalization, and institutional weaknesses while striving for long-term resilience and well-being. Southeastern Iran exemplifies such a context, where communities are compelled to adapt to rapidly changing environmental conditions, resource scarcity, and shifting socio-economic landscapes (Yazdanparast et al., 2023). At the heart of these adaptation processes lies Social Capital (SC)—the networks, norms, and trust that facilitate collective action and resource mobilization (Mensah, 2019; Ghorbani et al., 2018; Peluso et al., 2024). In such socio-ecological systems, adaptive capacity—the ability of communities to adjust to disturbances, learn from experiences, and reorganize while maintaining essential functions—becomes a critical determinant of long-term sustainability (Heydari et al., 2026).

This study is guided by a conceptual framework that positions social capital as a foundational driver of adaptive capacity in rural communities. Drawing on the Adaptive Capacity Wheel (Heydari et al., 2026) and social capital theory (Putnam, 2004; Bodin & Prell, 2011; Vongvisitsin, & Tung, 2025), we propose that the structural characteristics of social networks—specifically density, reciprocity, transitivity, and geodesic distance—serve as measurable proxies for the relational conditions that enable collective action, resource mobilization, and learning. These network properties are theoretically and empirically linked to community resilience and adaptive capacity (Ghorbani et al., 2024; Sadri et al., 2018). The framework thus operates at two levels: (1) direct measurement of social capital structures using SNA, and (2) conceptual inference about their contribution to adaptive capacity as a broader outcome. This approach allows us to identify which network configurations are most conducive to sustainable community development, while acknowledging that adaptive capacity itself requires direct empirical measurement in future research.

In rural contexts, where formal institutions may be weak or absent, SC becomes even more vital, underpinning collaboration, reducing transaction costs, and sustaining informal support systems that are often the backbone of local economies (Kietäväinen & Tuulentie, 2018; Ghorbani et al., 2021; Ghorbani et al., 2022; Luukkanen et al., 2019). For the rural communities of Southeastern Iran, strong social ties are not merely a cultural asset but a practical necessity. These ties enhance safety, facilitate the sharing of scarce resources, and foster a sense of collective well-being among populations that often face poverty and marginalization. However, the pursuit of sustainability in such settings is complex. It requires not only the protection of natural resources from unsustainable exploitation but also the promotion of equitable economic opportunities and the inclusion of all community groups in decision-making processes (Ghorbani et al., 2017; Mbah, 2019; Scott, 2015; Rapp, 2020; Adkins, 2021; Ghorbani et al., 2025). The multifaceted nature of SC—encompassing trust, reciprocity, and shared norms—demands sophisticated approaches for its measurement and management, especially if the goal is to achieve effective resource governance and inclusive development (Mohammadi et al., 2026).

Environmental degradation, for instance, does not affect all community members equally. The consequences are often uneven, with men and women experiencing different vulnerabilities and opportunities based on their access to and mobilization of social capital (Pisani & Micheletti, 2020).

This recognition has led to calls for more nuanced analyses that account for the intersectionality of SC with other social determinants, such as gender, class, and ethnicity.

Given the complexity of SC, traditional measurement approaches—such as surveys or qualitative interviews—often fall short in capturing the structural dimensions of social relationships. Social Network Analysis (SNA) has emerged as a promising methodological approach that addresses this gap by focusing on the patterns of trust and collaboration ties among individuals within a community (Bodin & Prell, 2011; Neumeyer et al., 2019; Rahimi et al., 2023). SNA enables researchers to map and quantify the relational structures that underpin SC, identifying key stakeholders, influential actors, and underrepresented subgroups (Rodriguez-Giron & Vanneste, 2019; Firuozpoor et al., 2015; Ghorbani, 2016; Garakani et al., 2025; Ghorbani, 2012; Borgatti et al., 2013). By visualizing networks of trust, reciprocity, and resource exchange, SNA provides a nuanced understanding of how collective action is facilitated or hindered within a community. One of the central advantages of SNA is its ability to reconcile individualistic and holistic perspectives, offering insights into both the micro-level dynamics of interpersonal relationships and the macro-level patterns that shape community resilience and participatory governance (Shariatyniya et al., 2025; HosseinYazdi et al., 2025; Shariatyniya et al., 2026).

The literature on SC in rural communities is extensive, with studies examining its role in diverse domains such as tourism (Di Paolo et al., 2025), resource access (Bott et al., 2020), and food security (Chriest & Niles, 2018). These studies have provided valuable insights into how SC supports community adaptation, resilience, and competitiveness. For example, Prayitno et al. (2022) explored the indicators of SC in the context of community adaptation during the COVID-19 pandemic in Indonesia, highlighting the importance of trust and cooperation in crisis response. However, much of this literature remains fragmented, lacking a critical synthesis that reveals overarching patterns, gaps, or controversies. Podgorskaya & Schitov (2021) discuss hidden intangible resources and rural competitiveness, but their analysis often remains descriptive rather than analytical. Similarly, Rivera et al. (2019) offer a broad perspective on the role of trust, cooperation, and cultural elements in agricultural and rural development, yet their findings underscore the need for deeper exploration of the mechanisms that facilitate these dynamics.

Existing Iranian research on social capital in rural development, while valuable, remains fragmented and predominantly descriptive. For instance, Ghorbani et al. (2015) examined SC within the same ICSP context but focused primarily on overall network density without disaggregating by gender or group type. Moghfeili et al. (2023) analyzed farmers' leadership networks in Iranian rural communities but did not explore how gender composition of groups affects network structure or collective action outcomes. Firuozpoor et al. (2015) applied SNA to rangeland stakeholders in Noor, yet their analysis remained at the descriptive level without comparative assessment across different group configurations. Avazpour et al. (2024) studied dryland co-management in Kerman province but did not examine the differential impacts of traditional versus mixed-gender groups. Saadi et al. (2016) examined rural women's entrepreneurial orientation in Iran but did not employ SNA to map network structures. None of these studies systematically compared traditional and gender-inclusive Village Development Groups (VDGs) to assess how organizational diversity shapes social capital structures and resource mobilization.

A further gap concerns gender dynamics. While Prasisca et al. (2015) demonstrated the importance of gender equality for SC in Indonesia, no study in the Iranian context has systematically compared network structures, density, reciprocity, transitivity, and centrality, across

male-only, female-only, and mixed-gender groups within the same development program. This is a critical omission given the culturally specific ways in which gender shapes access to networks, trust, and collective action in non-Western settings (Pisani & Micheletti, 2020).

Methodologically, prior SNA studies in Iran have typically relied on global network metrics without examining subgroup-level variations (Ghorbani et al., 2021; Rahimi et al., 2023; Shariatyniya et al., 2025). While these studies established the utility of SNA for understanding natural resource governance, they have not provided comparative assessments of different VDG organizational models (traditional vs. mixed-gender) or disaggregated network structures by gender subgroup. This limits the practical applicability of findings for designing gender-inclusive development interventions.

Sarbisheh was selected as the study site for three reasons. First, the ICSP has been active in this region since 2003, providing a well-documented context of community-based development interventions that allow for meaningful comparison of SC outcomes (Ghorbani et al., 2015). Second, Sarbisheh exhibits significant socio-cultural and economic diversity across its 40 project villages, with both traditional (male-only) and mixed-gender VDGs operating under the same institutional framework—an ideal setting for comparing how organizational structure affects SC. Third, the region faces acute environmental pressures (water scarcity, temperature extremes) and socioeconomic challenges (poverty, marginalization), making it a relevant and urgent case for studying how SC can enhance community resilience and adaptive capacity (Yazdanparast et al., 2023). The four specific villages, Chahl, Gazdez, Kasrab, and Tajmir, were purposively selected to represent maximum variation in VDG composition (traditional vs. mixed-gender) while sharing similar ecological, economic, and institutional contexts, enabling controlled comparisons.

This study offers three distinct contributions relative to prior Iranian research. First, unlike previous SNA studies that treated VDGs as homogeneous units, we disaggregate network structures by gender subgroup (men, women, and mixed-gender groups) within the same four villages, enabling direct comparison of how gender composition shapes collaboration and trust networks. Second, we move beyond descriptive metrics by linking network structures (density, reciprocity, transitivity, geodesic distance) to resource mobilization outcomes and participant satisfaction with decision-making, providing empirical evidence on which network configurations are most conducive to collective action. Third, we integrate quantitative SNA data with illustrative participant feedback to contextualize and validate the network findings, offering a more holistic assessment of SC dynamics than purely quantitative approaches. This combination of (1) comparative analysis across different VDG models, (2) subgroup-level disaggregation, and (3) integration of quantitative SNA with illustrative participant feedback (with SNA as the primary analytical tool) represents a methodological advancement over previous Iranian SC studies.

Guided by the above rationale, this study is structured around two main research questions:

1. How are the structural aspects of social capital linked to effective social resource mobilization in sustainable community development in Iran?

This question explores whether the patterns of trust and collaboration within VDGs are associated with stronger collective action and resource sharing, especially in the context of the ICSP.

2. To what extent can these structural aspects be objectively quantified and compared using Social Network Analysis?

This question examines the methodological effectiveness of SNA in capturing and distinguishing the complexities of social capital across different types of VDGs.

By addressing these questions, the study seeks to advance both theoretical understanding and practical approaches to fostering inclusive, resilient, and sustainable rural communities.

Material & Methods

• Study area

This research was conducted in Sarbisheh, a city located in South Khorasan province, approximately 66 kilometers southeast of Birjand in Eastern Iran. According to the 2016 national census, Sarbisheh is home to 8,715 residents across 2,362 families, resulting in a population density of 22.6 people per square kilometer—well below the national average of 44 people per square kilometer. The region is characterized by significant topographic diversity, with elevations ranging from 2,787 meters in mountainous zones to 1,550 meters in the plains. The climate is marked by extreme temperature fluctuations, with summer highs reaching 38°C and winter lows dropping to -25°C. Annual rainfall averages 228 mm, with higher precipitation observed in the upland areas.

Agriculture forms the backbone of Sarbisheh's economy, supported by fertile plains such as Hossein Abadghinab and Naz Dasht. Despite holding 9.9% of the province's natural resources, the area faces chronic water scarcity due to its arid climate. Since 2003, the ICSP has been active in Sarbisheh, promoting sustainable resource management and community-based development across 40 villages within a 200,000-hectare area (Ghorbani et al., 2015). This context provides a unique opportunity to examine the role of social capital in facilitating sustainable development under challenging environmental and socio-economic conditions.

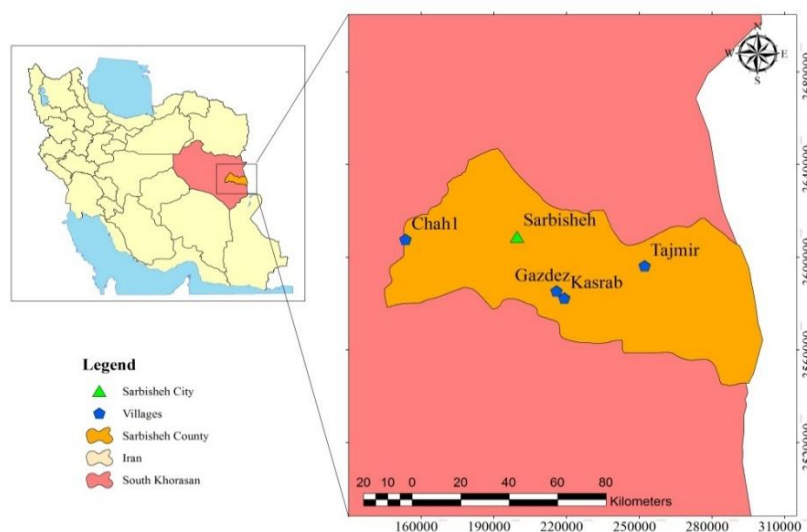


Figure 1. The location of the study area

- **Methods**

To investigate the structural characteristics of social capital and its implications for sustainable rural development, this study employed SNA method, which is grounded in graph theory and offers a robust framework for mapping and quantifying relationships within communities (Scott, 2015; Borgatti et al., 2013). By focusing on the patterns of trust and collaboration among community members, SNA enables the identification of key actors, subgroups, and the overall structure of social networks—elements critical for understanding collective action and resource governance.

Questionnaire Design and Data Collection

Data were collected using a structured questionnaire meticulously designed to capture the nuances of social capital within the selected villages. The instrument focused on two primary dimensions: trust and collaboration, both recognized as foundational components of social capital. Respondents were asked to evaluate their experiences and perceptions using a closed-ended 5-point Likert scale ranging from 1 (very low) to 5 (very high), allowing for the standardized quantification of subjective social dynamics.

The sampling strategy employed a purposive approach at two levels. First, villages were selected based on three criteria: VDG composition (traditional vs. mixed-gender), ecological and economic comparability, and community willingness to participate (see Village Selection Criteria above). Second, within each selected village, respondents were purposively sampled to include all active VDG members, ensuring representation of different gender, age, and leadership roles. This approach, consistent with established SNA studies (Bodin & Prell, 2011; Ghorbani et al., 2015), ensures that the sample captures the full diversity of network positions within each VDG while enabling controlled comparisons across villages. In total, 268 individuals participated in the survey, distributed as follows: Chah1 (58 respondents—34 men and 24 women), Gazdez (83 respondents—45 men and 38 women), Kasrab (56 respondents—31 men and 25 women), and Tajmir (71 respondents—25 men and 46 women). This sample ensured robust data for both overall and gender-based analyses.

To ensure cultural sensitivity and maximize response accuracy, local assistants from each village were recruited and trained to administer the questionnaires. Their involvement was crucial in overcoming language barriers, building trust with respondents, and encouraging candid participation. Data collection was conducted during the spring and summer of 2015, a period selected to optimize accessibility and respondent availability.

Although the data were collected in 2015, they remain methodologically and policy-relevant for three reasons. First, the ICSP continues to operate in Sarbisheh with the same institutional framework, making these baseline network data valuable for assessing long-term changes and intervention impacts. Second, studies on social capital and network structures in rural Iran remain

scarce, and this dataset provides a rare empirical benchmark against which future research can be compared. Third, the structural patterns identified, particularly regarding gender-inclusive network design, offer transferable insights for ongoing and future development programs in similar arid regions, where institutional constraints and environmental pressures persist. Thus, while not recent, these data provide foundational knowledge that remains applicable to current policy and practice.

Data Processing and Validation

Following data collection, a rigorous multi-step process was implemented to ensure data quality and reliability. The initial phase involved comprehensive data cleaning, where responses were reviewed for completeness and consistency. In cases of missing or ambiguous responses, the research team attempted follow-up with participants to clarify or supplement the data, thereby minimizing information gaps.

For SNA purposes, responses on the 1–5 Likert scale were dichotomized using a cut-off value of 3, in line with established SNA protocols (Borgatti et al., 2013). Responses above this threshold were coded as indicating the presence of a social tie, while those below were considered as the absence of a tie. This dichotomization facilitated the construction of binary network matrices, allowing the analysis to focus on the most significant and actionable relationships within the community networks.

Subsequent validation involved detailed examination of the constructed social networks for anomalies such as missing nodes (individuals) or erroneous ties (connections). The research team adhered to best practices in SNA, cross-checking network data for accuracy and consistency. Where uncertainties persisted, external audits and reviews were conducted by SESM-Lab personnel to provide an additional layer of oversight and ensure methodological rigor.

Ethical Considerations

All research activities were conducted in accordance with ethical guidelines for social science research. Informed consent was obtained from all participants, and confidentiality was strictly maintained throughout the study. The involvement of local assistants further ensured that cultural norms and sensitivities were respected during data collection.

Results

The social fabric of rural communities in Southeastern Iran reveals itself through intricate patterns of connection, trust, and collaboration. Our SNA of the four VDGs—Chah1, Gazdez, Kasrab, and Tajmir—uncovered a rich tapestry of relationships that shape how these communities mobilize resources, make decisions, and pursue sustainable development. The story that emerges from our data is one of contrast and complexity, where traditional and mixed-gender groups demonstrate different strengths and challenges in building SC.

When we first mapped the social networks in each village, as shown in Figure 2, the visual differences were striking. Tajmir's network appears as a dense constellation of interconnected points, with lines crisscrossing between nearly every member. This visual impression is confirmed by the quantitative data in Table 1, which reveals Tajmir's remarkable collaboration density index of 70.3%—the highest among all four villages. This means that more than two-thirds of all possible collaborative relationships within Tajmir have been realized, creating a tightly-woven social fabric where information, resources, and support flow freely among community members.

The networks in Chah1, Gazdez, and Kasrab tell a different story. While still functional, these communities show more modest collaboration densities ranging from 45% to 60%. Particularly interesting is Gazdez, where the mixed-gender composition of the VDG seems to foster a moderate level of collaboration. Though not as densely connected as Tajmir, Gazdez's network demonstrates that gender-inclusive groups can create substantial collaborative bonds, challenging traditional assumptions about gender segregation and community effectiveness.

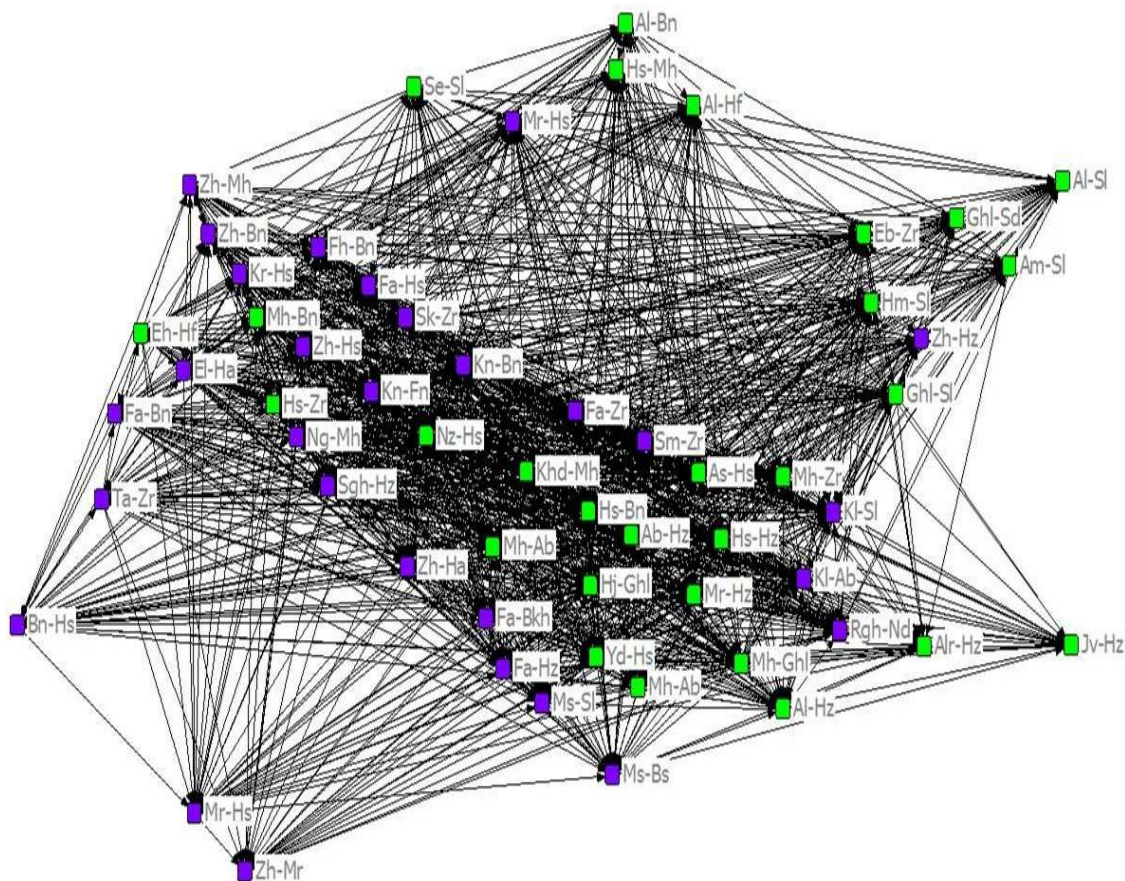


Figure 2. Chah1 Village: Trust Network

Table 1. Sarbisheh Region: Density, Reciprocity, Transitivity and Geodesic Distance

Village	Network	Density	No. of Ties	Reciprocity (Dyad Based)	Transitivity (Triad Based)	Avg. Geodesic Distance	Compactness
Tajmir Men	Collaboration	0.703	422	0.681	0.516	1.255	0.811
Tajmir Men	Trust	0.682	409	0.669	0.485	1.445	0.823
Chahl	Trust	0.581	1921	0.474	0.397	1.425	0.790
Gazdez Men	Trust	0.570	1129	0.478	0.381	1.43	0.785
Tajmir Women	Trust	0.492	1017	0.434	0.392	1.547	0.739
Gazdez Women	Trust	0.484	680	0.478	0.307	1.518	0.741
Gazdez Men	Collaboration	0.469	929	0.399	0.327	1.533	0.734
Tajmir Women	Collaboration	0.462	957	0.409	0.436	1.625	0.713
Chahl	Collaboration	0.448	1480	0.363	0.361	1.58	0.719
Kasrab	Trust	0.383	1181	0.318	0.352	1.682	0.681
Gazdez Women	Collaboration	0.373	524	0.397	0.284	1.674	0.679
Kasrab	Collaboration	0.344	1060	0.330	0.346	1.697	0.655

Beyond simply counting connections, we examined the quality of these relationships through measures of reciprocity and trust. As Table 2 illustrates, Tajmir again leads with over 65% of its relationships being mutual—people not only receive support but also give it in return. Gazdez follows closely, its high reciprocity suggesting that mixed-gender groups may foster balanced, two-way relationships. The trust networks visualized in Figure 3 mirror these findings, with stronger, more reciprocal networks also showing higher average trust scores.

Chahl and Kasrab, while still maintaining meaningful community bonds, show more one-sided relationships. In these villages, support and collaboration often flow in one direction rather than being mutually exchanged. This pattern suggests that the most resilient communities are those where social capital is not just accumulated but actively circulated, with trust and support flowing back and forth between members.

Table 2. Sarbisheh Region, Group Density

Village	Network	Group	Density (%)
Tajmir Men	Collaboration	2	94%
Tajmir Men	Trust	2	92%
Tajmir Women	Trust	3	91%
Tajmir Women	Collaboration	3	89%
Gazdez Men	Trust	2	80%
Gazdez Men	Trust	1	80%
Gazdez Women	Trust	2	76%

[illegible]

Figure 3. Chah1 Village: Collaboration Network

Looking more closely at individual positions within these networks, our centrality analysis identified key actors who serve as bridges and connectors. Table 3 highlights these influential individuals in each village—those who link different parts of the network and facilitate collective action. In Tajmir and Gazdez, these central figures often hold formal or informal leadership roles, coordinating activities and resolving conflicts. What stands out in Gazdez is that both men and women occupy these central positions, suggesting that gender-inclusive leadership enhances network cohesion and broadens participation.

The traditional VDGs in Chah1 and Kasrab present a more hierarchical structure, with influence concentrated among a smaller number of individuals—typically men. While this arrangement can be efficient for certain tasks, it may limit the diversity of perspectives and resources available to the community, potentially making these groups less adaptable to complex challenges.

The comparison between mixed-gender and traditional VDGs reveals fascinating insights about gender dynamics and inclusivity. Mixed-gender groups like Gazdez not only show higher reciprocity but also a more balanced distribution of influence. Members report greater satisfaction with decision-making processes and a stronger sense of collective capability. As one female participant from Gazdez explained: "When both men and women have a voice, we find better solutions because we see problems from different angles." This sentiment was echoed by many others, highlighting how gender inclusion enriches the social capital of communities.

Traditional VDGs, while effective at mobilizing resources for specific purposes, tend to be more rigid in their structure and less responsive to diverse needs. As one respondent from Kasrab noted: "Decisions are made quickly, but sometimes important perspectives are missed." This observation underscores how the structure of social networks shapes not just who participates but also how communities adapt and respond to challenges.

Table 3. Sarbisheh Region: Internal and External ties

Village	Network	Network E-I index	Group	E-I-Group
Gazdez Men	Collaboration	0.157	1	0.112
Gazdez Men	Collaboration	0.157	2	0.103
Gazdez Men	Collaboration	0.157	3	0.298
Gazdez Men	Trust	0.22	1	0.197
Gazdez Men	Trust	0.22	2	0.154
Gazdez Men	Trust	0.22	3	0.362
Kasrab	Collaboration	0.448	1	0.426
Kasrab	Collaboration	0.448	2	0.376
Kasrab	Collaboration	0.448	3	0.5
Kasrab	Collaboration	0.448	4	0.533
Kasrab	Trust	0.46	1	0.426
Kasrab	Trust	0.46	2	0.357
Kasrab	Trust	0.46	3	0.533
Kasrab	Trust	0.46	4	0.607
Tajmir Women	Collaboration	0.122	1	0.26

Tajmir Women	Collaboration	0.122	2	0.391
Tajmir Women	Collaboration	0.122	3	-0.058

Across all four villages, the International Carbon Sequestration Project (ICSP) has played a transformative role in shaping social capital. Figure 4 captures participants' assessments of how the ICSP has influenced trust and collaboration in their communities. Tajmir and Gazdez report the strongest positive impact, suggesting that the project's emphasis on participatory approaches and inclusive decision-making has been particularly effective in these villages.

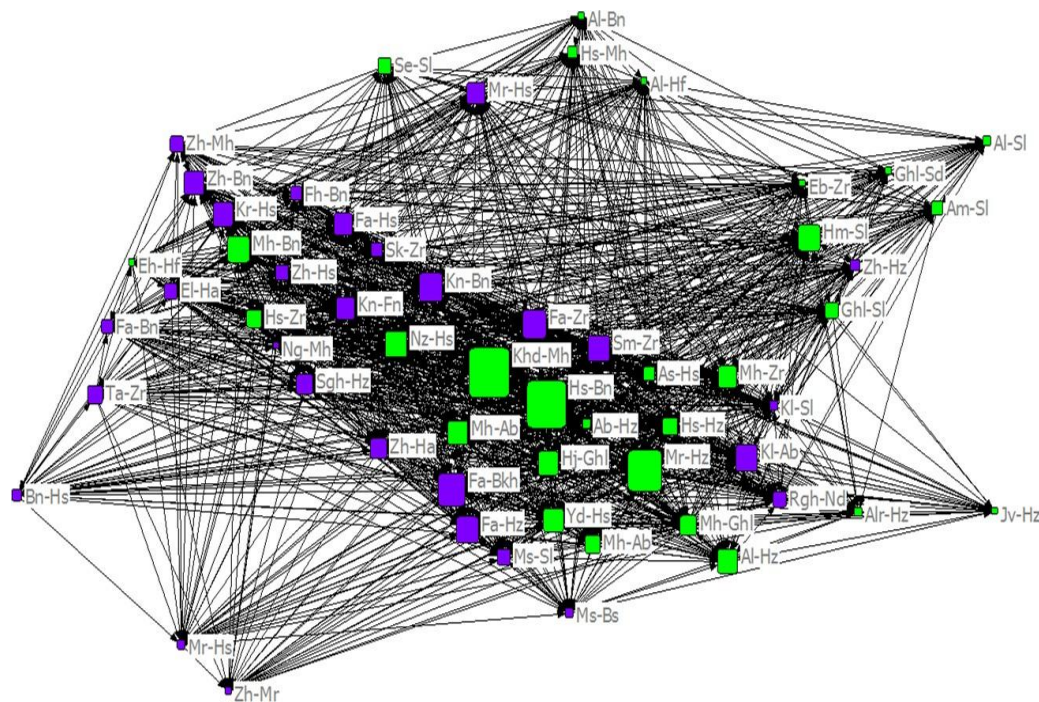


Figure 4. Chah1 Village: Trust Network, Freeman In-Betweenness

The participant feedback summarized in Table 4 provides rich context for these findings. Respondents frequently mentioned how the ICSP created spaces for dialogue, provided training that built confidence, and established shared goals that brought community members together. "Before the project, we worked separately," explained an elder from Tajmir. "Now we understand that by working together, we can achieve much more." Women in mixed-gender groups especially valued the project's role in creating opportunities for their voices to be heard. "The ICSP meetings were the first time many men listened to our ideas about land management," shared a female participant from Gazdez.

What emerges from this tapestry of quantitative and qualitative data is a compelling picture of how SC—in its various structural forms—shapes the capacity of rural communities to pursue sustainable development. Villages with denser, more reciprocal, and more inclusive networks consistently demonstrate higher levels of trust, broader participation, and greater collective efficacy. These communities are better equipped to share knowledge, pool resources, and adapt to changing circumstances—all essential capabilities for sustainable development.

The successful application of SNA in this context demonstrates its value as a methodological tool for understanding the complex social dynamics that underpin community resilience and resource governance. By mapping and measuring the structure of relationships, SNA provides insights that might otherwise remain hidden, offering a foundation for more targeted and effective interventions.

The story told by our data is ultimately one of connection and transformation—how the patterns of trust and collaboration that bind communities together can be strengthened and reshaped through intentional efforts like the ICSP. It suggests that building social capital is not just about creating more connections but about fostering the right kind of connections: reciprocal, inclusive, and distributed across diverse community members. This insight offers a powerful lens for understanding and supporting sustainable development in rural communities, not just in Southeastern Iran but in similar contexts worldwide.

Table 4. Representative Qualitative Feedback on the Impact of the ICSP on Social Capital and Community Participation

Village	Respondent Type	Example Feedback
Tajmir	Elder (Male)	<i>"Before the project, we worked separately. Now we understand that by working together, we can achieve much more."</i>
Gazdez	Woman	<i>"The ICSP meetings were the first time many men listened to our ideas about land management."</i>
Kasrab	Youth (Male)	<i>"With ICSP training, I felt more confident to participate in group decisions."</i>
Chahl	Woman	<i>"Now, our voices are heard, and we feel more responsible for the village's future."</i>
Gazdez	Man	<i>"Mixed groups have brought new perspectives. We solve problems faster and with more creativity."</i>
Tajmir	Woman	<i>"Collaboration is easier now; trust has grown among us, especially between men and women."</i>

Discussion

This study investigated how collaboration, trust, and gender dynamics within rural social networks shape community resilience and development trajectories. Focusing on four villages participating in the ICSP and employing SNA as the primary analytical tool, we examined the structural conditions that enable or constrain collective action and resource mobilization. The findings not only affirm the centrality of SC in sustainable rural development, as highlighted in the literature (Peluso et al., 2024; Mensah, 2019), but also offer new perspectives on the mechanisms through which social networks influence collective action, adaptation, and empowerment.

Social Capital, Network Analysis, and Sustainable Development Outcomes

Traditional metrics such as improvements in human development indices or rangeland quality provide essential benchmarks for assessing development. However, our application of SNA reveals the often-invisible social dynamics that underpin these outcomes. By visualizing and quantifying the structure of relationships within VDGs, SNA enables stakeholders to diagnose why certain development initiatives succeed while others falter (Avazpour et al., 2024). The network maps and density indices from this study clearly demonstrate that Tajmir's high collaboration density (70.3%) is an indicator of vibrant, trust-based social capital that facilitates rapid mobilization and effective resource sharing. Understanding why Tajmir achieved such high density requires examining its institutional history. Unlike Kasrab and Chahl, Tajmir's VDG leadership has actively promoted inclusive membership and regular community meetings, creating repeated opportunities for trust-building and collaboration. This institutionalized approach to participation has generated network effects that perpetuate themselves: dense networks create trust, trust encourages participation, and participation further densifies networks. Conversely, Chahl and Kasrab, lacking such intentional network-building practices, have remained more fragmented. These insights highlight the importance of fostering reciprocal, inclusive connections that bridge different groups within the community (Bodin & Prell, 2011; Rodriguez-Giron & Vanneste, 2019).

Emerging from this analysis is a clear message: social capital is not simply an adjunct to economic or physical resources, but a foundational asset that enables communities to leverage all other forms of capital. As trust and collaboration increase, so too does community engagement in socio-economic projects, paving the way for enhanced cooperation, innovation, and investment in rural areas (Ghorbani & Azadi, 2021; Rivera et al., 2019). The broader literature supports the view that SC drives the interactions that underpin successful rural development (Rivera et al., 2019). Our study adds to this dialogue by demonstrating how SNA can be used to map, measure, and strengthen the social fabric of rural communities.

The practical implications are significant. Development interventions should prioritize inclusive, participatory structures, that foster high-density, reciprocal networks. Specifically, we recommend that: (1) project designers formally mandate mixed-gender participation in all

community decision-making bodies to ensure women's voices are systematically included; (2) training programs be implemented to build leadership and facilitation skills among both men and women, with particular attention to women's confidence and public speaking; (3) regular community meetings (at least monthly) be institutionalized to create repeated opportunities for trust-building and information exchange; (4) SNA be conducted as a baseline diagnostic at the outset of development projects to identify existing network strengths (e.g., central actors, bridging ties) and weaknesses (e.g., isolated subgroups, gender gaps), allowing interventions to be tailored accordingly; and (5) SNA be repeated periodically (e.g., every 2–3 years) to monitor changes in network structure and evaluate the effectiveness of interventions over time. Programs like the ICSP, which emphasize group-based activities and shared decision-making, can serve as effective models, provided they incorporate these specific design features. For policymakers, these findings suggest that funding should be conditional on inclusive VDG composition and that capacity-building budgets should explicitly allocate resources for gender-sensitive leadership training.

Gender and Network Structure

One of the most compelling findings of this research is the distinct patterning of male and female social networks and the transformative impact of gender inclusion. In line with Saadi et al. (2016), our analysis shows that women's VDGs, while sometimes more tightly clustered, are increasingly expanding their networks and influence. The mixed-gender group in Gazdez exhibited high reciprocity and a balanced distribution of centrality, with both men and women occupying key leadership positions. This pattern can be explained by the institutional design of mixed-gender VDGs, which intentionally create spaces for women's participation in decision-making—spaces absent in traditional male-dominated groups. Over time, this structural inclusion has normalized women's leadership. This aligns with Prasisca et al. (2015) and Ghorbani et al. (2024), who argue that gender equality is a catalyst for stronger, more adaptive social capital. In contrast, traditional VDGs in Chah1 and Kasrab lack such institutional mechanisms, perpetuating male-dominated hierarchies that limit network diversity and adaptive capacity.

Conversely, traditional male-dominated VDGs, while often efficient in mobilizing resources, tended to be more hierarchical and less responsive to diverse perspectives. The higher trust density observed in male networks suggests a more dyadic structure, consistent with Matsuda's (2000) theory of interpersonal relationships. However, women's growing participation is gradually reshaping these dynamics. Religious leaders and other respected figures often serve as focal points for building trust and bridging divides (Guarnacci, 2016), yet persistent barriers for marginalized groups—especially women—remain, highlighting the need for continued attention to social and cultural factors.

The variability in network characteristics across the four villages underscores the context-specific nature of social capital. Tajmir's exceptional density (70.3%) reflects a combination of

historical and institutional factors, including earlier community-based initiatives that predate the ICSP (Ghorbani et al., 2015) and inclusive leadership that fosters cross-cutting ties. This contrasts with Kasrab, where hierarchical leadership has concentrated decision-making power among a few individuals. The sharp increase in trust density among village leaders echoes Ryan and Urgenson's (2019) emphasis on participatory capacity for collaborative management. Our observed densities are higher than those reported by Ghorbani et al. (2021) in similar Iranian contexts (35–50%), likely due to the ICSP's longer implementation and emphasis on mixed-gender groups. Unlike Ghorbani et al. (2022) and Rahimi et al. (2023), who did not disaggregate by gender, our findings reveal that women in mixed-gender groups achieve density levels comparable to men, challenging assumptions that women's networks are inherently weaker.

Our findings reveal several mechanisms through which network structures influence sustainable development. High network density reduces the costs of collective action by enabling rapid information diffusion and coordination (Ghorbani & Azadi, 2021). Reciprocity fosters trust and long-term cooperation, reducing free-riding and ensuring sustained collective resource management (Ostrom, 1990; Ghorbani & Azadi, 2021). Inclusive network structures—particularly mixed-gender VDGs—enhance diversity of perspectives and knowledge, leading to more adaptive solutions (Prasisca et al., 2015; Ghorbani et al., 2024). Bridging social capital, strengthened through ICSP interventions, enables communities to leverage external support. These mechanisms collectively demonstrate that sustainable development is fundamentally shaped by the architecture of social relationships.

However, the sustainability of these gains remains uncertain. Our cross-sectional design provides a snapshot, but without longitudinal data, it is difficult to assess whether these patterns will persist. As Sadri et al. (2018) have shown, communities with robust networks are better able to recover from adversity, indicating that social bonds cultivated through ICSP initiatives contribute to community resilience. Integrating SC data with economic and ecological indicators, as advocated by Ghorbani et al. (2022) and Luukkanen et al. (2019), would provide a more comprehensive assessment of sustainability.

Limitations and Future Directions

While this study advances understanding of SC in rural Iran, several methodological and statistical limitations must be acknowledged. First, the cross-sectional design provides a snapshot of network structures at a single point in time (2015) and cannot capture the evolution of social capital or establish causal relationships between network characteristics and development outcomes. Second, adaptive capacity is treated as a conceptual framework rather than an empirically measured variable, limiting direct claims about resilience outcomes. Third, the purposive sampling of four villages, while appropriate for comparative analysis, limits generalizability to the full diversity of Iranian rural communities. Fourth, despite efforts to

minimize social desirability bias through local assistants, self-reported trust and collaboration may not fully reflect actual behaviors. Fifth, the dichotomization of Likert-scale responses (using a cut-off of 3), while standard in SNA, inevitably simplifies the gradation of social relationships and disregards tie intensity and quality, potentially losing nuance in trust and collaboration strength. Sixth, we did not control for potentially confounding variables such as age, education, income levels, or length of ICSP participation, which may influence both network position and development outcomes. Seventh, our analysis focuses on the village-level network structure without examining broader multi-level dynamics (e.g., inter-village networks or connections to external institutions), which may also shape resource access and adaptive capacity. Eighth, the reliance on a single analytical method (SNA) without triangulation with other quantitative techniques (e.g., regression analysis) limits our ability to isolate the unique contribution of network structures relative to other factors.

Future research should employ longitudinal designs to track network evolution and enable causal inference, integrate direct indicators of adaptive capacity, expand the sample to include more diverse villages, incorporate continuous measures of tie strength to preserve relationship gradation, control for relevant confounders (age, education, income, project duration), adopt multi-level network analysis to capture cross-scale dynamics, and combine SNA with complementary quantitative methods (e.g., regression or QCA) to better isolate the effects of network structures on development outcomes.

Conclusions

This study set out to examine how structural aspects of social capital influence resource mobilization and sustainable development in rural Iran, and to assess the effectiveness of SNA in quantifying these structures. Our analysis of four ICSP-participating villages in Southeastern Iran provides clear answers to both research questions.

Regarding the first question, how structural aspects of SC link to resource mobilization, we found that dense, reciprocal, and transitive networks significantly enhance collective action. Villages with higher collaboration density (Tajmir, 70.3%) and reciprocity (over 65%) demonstrated faster resource mobilization, more effective coordination, and greater member satisfaction with decision-making. Mixed-gender groups, in particular, exhibited more balanced leadership distribution and stronger trust networks compared to traditional male-dominated VDGs.

Regarding the second question, the effectiveness of SNA in quantifying these structures, we demonstrated that SNA successfully captured and distinguished network complexities across different VDG types. Key metrics (density, reciprocity, transitivity, geodesic distance) provided objective, comparable indicators of social capital that align with qualitative participant feedback, validating SNA as a robust diagnostic tool for rural development research.

Theoretically, this study advances the literature by empirically demonstrating that gender-inclusive institutional design generates denser, more reciprocal networks, a causal mechanism previously assumed but not demonstrated in the Iranian context. Practically, our findings recommend gender-inclusive participatory structures and sustained capacity-building as drivers of sustainable rural development. SNA should be adopted as a diagnostic tool for identifying network strengths, targeting interventions, and monitoring impacts over time. Future research should employ longitudinal designs, integrate direct indicators of adaptive capacity, and control for confounders to establish stronger causal links between network structures and development outcomes.

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CRedit authorship contribution statement

All authors contributed equally to the conceptualization of the article and writing of the original and subsequent drafts.

Conflict of interest

The authors declare no conflict of interest.

Ethical considerations

The authors avoided data fabrication, falsification, and plagiarism, and any form of misconduct.

Data availability statement

Not applicable.

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