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Talking water: interplay of gender, trust and expertise in agricultural extension groups in Mendoza, Argentina

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Abstract

Stakeholder adaptation is a critical strategy to overcome changing climate patterns worldwide. Still it relies on the speed and effectiveness of information flow to end-users. Research shows that the loss of information in several stages of its spread and learning from peers is more important than the knowledge circulated by extension services. Women's participation and contribution are supportive and strategic, depending on the level of agreement and the interplay of trust variables within the network.

In the arid Andes, agriculture is central and dependent on water management and macroeconomic conditions that shape market prospects, irrigation practices, and stakeholder behavior. Data were collected using the platform of a capacity-building program for organisations of water users in the Diamante and Atuel River basins in Mendoza, Argentina.

Social Network Analysis (SNA) contributes to unveiling the cornerstones of information flow by identifying group structures, strong bonds, and bottlenecks in water management systems. In the first step, we evaluated the characteristics (density, centrality, average shortest path, and degree) of the pre-existing relationships and five sub-topic networks. Second, we compare networks containing pre-existing links only with those formed during the lecture. Emphasizing adaptation practices to cope with climate change impacts, the results provide valuable insights into the intricate interplay of gender dynamics, trust, expertise recognition, and discussion patterns within water and agricultural extension groups in Argentina.

These insights highlight the ongoing need to promote gender equity, address biases in expertise recognition, and leverage trust for meaningful knowledge exchanges within evolving social contexts. It also reveals the alignment of Argentina's gender performance with similar production setups in Southern America or the Global North, highlighting the universality of challenges and opportunities in fostering inclusive and equitable participation. Our findings indicate that each group within the two river basins exhibits numerous pre-existing links and tends to be less accessible to newcomers, resulting in a shorter average path. Thus, information can spread faster. Trust is an underlying facilitator for sensible topics and a catalyzer for communication.

Keywords: social network analysis; SNA; gender; Mendoza, Argentina; water management

Introduction

Water resources are under pressure worldwide (UN Water, 2023; Zaveri et al., 2023). Despite increasing demand across various sectors (UN Water, 2022), the agricultural sector remains the predominant consumer. Consequently, the agroindustry not only contends with inter-sector competition but also has to anticipate intensified water scarcity due to diverse climatic influences in the near term (FAO, 2023).Irrigation is an advocated approach aimed at enhancing water use efficiency, minimizing water wastage, and ensuring the stability of water supply (FAO, 2023; UN Water, 2022). Food and fiber production on irrigated land is almost fourfold the production of rainfed land (FAO, 2021). Despite that ancient or alternative solutions that could diminish this gap have been identified and developed, there are innumerous reasons why stakeholders have not yet adopted them.

Argentina is not exempt as 75% of its territory is classified as sub-humid, arid or semi-arid. Recent droughts have inflicted damages ranging between 6 and 8 billion US dollars (OECD, 2018). In the central-west of the country, irrigation valleys in the Andes coexist with areas with salinization and phreatic slumps problems, while overgrazing and deforestation are the most important problems in the plains (Torres et al., 2015). These processes affect the quantity and quality of surface and underground water resources. However, deficiencies in the irrigation infrastructure, inadequate land systemization, poor water management, and a lack of technical assistance to producers have led an important surface area experiencing problems of salinization and/or phreatic resurgence.

In the Argentinian province of Mendoza, the importance placed on water is justified by the arid climate conditions and consequently the need to manage its limited availability. The annual precipitation in the province varies from 120 mm in the north to 380 mm in the south. Using water, they have developed in the plain area, irrigation oases that occupy an area of about 300,000 hectares that constitutes only 3.5 % of the total area that represent the interaction and the complexity of the productive and social ecosystem in these oases, agro-urban-industrial conglomerates.

This general knowledge for adaptation is not confined to individuals, as institutions also support capacity building for their end-users (Torres et al., 2015). Institutions responsible for natural resource management must foster resilience internally, predominantly, and within their spheres of action (Saravia Matus et al., 2022). Exacerbating climate change will significantly amplify the importance of capacity building, as effective adaptation to climate change hinges critically on the capacities of both individuals and institutions (Dev & Manalo IV, 2023;Fletcher et al., 2021). A special case is Mendoza, which holds the oldest water constitution in the Americas, along with water organizational bodies recognized for their autonomy and stakeholder representation. The Departamento General de Irrigación (DGI) is the governing body with respect to water usage and administration in the region. Given its economic reliance on agroindustry and its pivotal role in the semi-arid Andes, the province's development is

heavily tied to water management and broader macroeconomic conditions influencing market prospects, irrigation practices, and stakeholder behavior.

Considerable increments in water productivity require capacity building to optimize the available resources, foster stakeholder representativeness and adopt viable technologies (Saravia Matus et al., 2023; Torres et al,. 2015). Global estimates of water capacity building indicate that at least 1 million people should receive training annually to serve a population effectively or provide services to 7.5 billion people (OECD, 2020; FAO, 2023). Recent literature emphasizes the importance of tailoring policies based on stakeholder communication of mapping stakeholders' communication according to their group structures and characteristics, enhancing the effectiveness of local practices (Aguilar Revelo, 2021; Barrett et al., 2022).

The dissemination of information is strongly shaped by stakeholder group composition, structure, dynamics, and interests (Granovetter, 1985; Easley & Kleinberg, 2010; Borgatti et al., 2018).Complexity further increases in water-linked organizations, where information diffusion can range from bureaucratic patterns to simple word-of-mouth. Water management measures have evolved from ready-to-implement practices to stimulating group decision processes, backed by evidence-based outcomes (Chaxel et al., 2018; Imburgia et al., 2021). Within these distinct contexts, policy effectiveness relies on the program publicity and power dynamics rather than the innovation itself (Saravia Matus et al., 2022; Torres et al., 2015). This could potentially lead to minorities' voices being marginalized and excluded from decision-making processes due to structural barriers in information flow (Auguste & Bricker, 2017; Boelens, 2015; Imburgia et al., 2021).

The current climate change projections coupled with existing gender imbalance could exacerbate the socioeconomic inequalities if limited access to resources and capacity building persists (Njuki et al., 2023; Kristjanson et al., 2017; Huyer, 2016; Dev & Manalo IV, 2023). Recognizing the unquestionable benefits of women's empowerment in the agricultural sector(FAO 2023), research has yet to provide sufficient evidence on the linkage of women empowerment and agricultural productivity and technology adoption, despite a consensus on the benefits of the matter (Meinzen-Dick et al. 2019;Njuki et al., 2023; Kristjanson et al., 2017; Huyer, 2016).

This paper aims to highlight the relevance of women's participation in extension groups by acknowledging their involvement in agricultural production networks and assessing their contribution to spread technical information, which could lead to technological adoption in terms of water management and climate change adaptation.

Recent studies underscore the importance of recognizing women's roles in agricultural and water organizations across different setups to shift complex social norms, work culture, incentives, and policies, fostering more equitable and diverse systems (Aguilar Revelo2022; Cohen& Shinwell 2020;

Imbruglia et al. 2021). Collective action and group-based approaches offer effective tools for inclusive development (FAO 2023; Fernández-Giménez et al. 2022; Serpossian et al. 2022).

Additionally, by promoting community participation, it stimulates awareness on sustainable water resource management (Saravia Matus et al. 2022; Fletcher et al. 2021),which is crucial in a province where the agricultural sector accounts for a stake of 82% of the water consumption. Thus, this study focuses on the basin level to emphasize gender roles, empowerment, technical efficiency, and integration of physical, social, and economic aspects in the face of deteriorating conditions.

Social Network Analysis (SNA) is a valuable tool in the social sciences for studying interactions among group members, the dynamics of information dissemination, and revealing patterns of connections. By analyzing relations between individuals, SNA unveils information flow pathways which are important for building adaptive capacity and management of natural resources (Faulkner & Nkwake, 2017; Lin et al., 2021; Esparcia & Serrano, 2016; Hermans et al., 2017; Easley & Kleinberg, 2010; Borgatti et al., 2018; Bodin & Crona, 2009). This supports an understanding of how information travels. SNA identifies key individuals within group settings that drive information dissemination by occupying critical positions. These influential nodes accelerate and broker the spread of information (Lin et al., 2021; Bodin & Crona, 2009). SNA also locates bottlenecks and bridges, which connect separate network components.

This paper uses SNA to study two groups and their interactions across five predefined sub-topics: *water distribution*, *irrigation practices*, *input prices*, *market prospects*, and *climate contingencies*. One group resides in the Diamante River basin, the other in the Atuel basin. The Diamante River originates from glaciers, flowing eastward to the Desaguadero River, covering 12,523 sq km in Mendoza's central and southern regions. The Atuel basin spans around 29,721 sq km, encompassing parts of the San Rafael, General Alvear, and Malargüe Departments, with the Atuel River spanning about 545 km (DGI 2016, SAGyP 2006).

The findings unveil insightful dynamics in group interactions and gender roles, highlighting trust's importance in shaping discussions and the often-under represented role of women. While both groups favour familiar participants, men notably exhibit greater openness to new connections. Both groups share a strong focus on discussions concerning water distribution. Despite their lower participation rate, women are indispensable, particularly in the Atuel network. Here, women hold strategic network positions as pivotal information flow and connectivity hubs. Surprisingly, these women, constituting less than a third of the group, control 36% of hub positions and 18% of authority positions.

Empowering women in agriculture emerges as a catalyst for enhancing information dissemination and group coherence (Esparcia & Serrano, 2016). This study underscores women's pivotal role as information brokers, enhancing agricultural initiatives through their active involvement. This finding

emphasizes the need to acknowledge and support women's contributions within such groups. The paper highlights the pivotal role of empowering women for effective information dissemination on water distribution in agriculture, showcasing their potential as information brokers. Promoting women's engagement is critical to enhancing agricultural initiatives, fostering information flow, and reinforcing group cohesion (UN Women, 2023; Saravia Matus et al., 2022).

The next section describes the data collected and the methodology applied for SNA. Results and implications are discussed in the following section unveil the cornerstones of information flow to conclude on the main results and highlights of the analysis by identifying virtuous communication bonds and bottlenecks of information flow that could improve resilience and governance of the irrigation systems.

Background literature

Historically, equity and gender issues have been intertwined with issues concerning water and land management in Latin America revealing disparities in irrigation practices based on farm size (FAO, 2021, 2023). Water policies continued to follow generalized perspectives neglecting local knowledge and gender considerations, despite the increasing integration of gender perspectives in development plans and policies (Cohen& Shinwell, 2020; WWAP, 2012).

Building adaptive capacity is a crucial necessity in confronting the challenges posed by climate change. Despite the urgency, gender imbalances persist (Abbassim, 2021), contributing to the disproportionate impact of extreme weather events on women (Serpossian et al., 2022). Presently, women are more exposed to shocks and experience diverse effects compared to men, reflecting a higher vulnerability to climate change. (Dev & Manolo IV, 2023; Kristjanson et al., 2019; Anderson & Sriram, 2019)

A notable issue lies in the gender-blind nature of most climate adaptation measures, programs, and technological innovations. Institutional priorities must undergo a transformation to address this oversight (Saravia Matus et al., 2022). Inefficient information flow and the non-recognition of gender differences in preferences and specific knowledge often result in the absence of women from decision-making processes. (Anderson & Sriram, 2019; Quisumbing et al., 2023; Huyer, 2016; Agarwal, 2000). Recent studies have illuminated the relevance of acknowledging women’s contribution in agricultural and water organizations across diverse contexts (FAO, 2023; UN Women, 2023).It is evident that when actively empowered, women can play a vital role in extension and adaptation programs (Fletcher et al. 2021; FAO 2023). Gender imbalances pose a significant barrier to building adaptive capacities, emphasizing the need for a paradigm shift in institutional perspectives. (Kristjanson et al., 2019; Quisumbing et al., 2023; Huyer, 2016; Agarwal, 2000; Esparcia & Serrano, 2016; Saravia Matus et al., 2022)

These insights offer pathways for transforming intricate social norms, work culture, incentives and policies, fostering more inclusive and diverse systems (Aguilar Revelo,2022; Cohen& Shinwell, 2020). Leveraging collective action and group-based approaches is an effective tool for advancing inclusive development (FAO, 2023; Fernández-Giménez et al., 2022; Serpossian et al., 2022). In mixed groups, the divergence in needs, capabilities, and preferences between women and men underscores the necessity for gender-sensitive capacity building and interventions (Seirpossian, 2018; Kristjanson et al., 2019). Recognizing that women often rely on informal information sources and networks while men have stronger connections to formal sources, the creation of appropriate opportunities for women to participate becomes imperative (Glazebrook et al., 2020; Westermann et al., 2005).

The benefits of women empowerment in the agricultural sector are well-established (FAO, 2023), yet the extent of its impact on agricultural productivity and technology adoption remains insufficiently verified despite consensus (Meinzen-Dick et al., 2019; UN Women, 2023). Social norms and gender roles, however, continue to hinder women from active participation in decision-making and natural resource management (Quisumbing et al., 2023; Njuki et al., 2023; Agarwal, 2000). Despite these challenges, women are three times more likely to adopt sustainable practices (Glazebrook et al., 2020). Furthermore, when women collaborate in groups, there is often enhanced collaboration, solidarity, and conflict resolution, emphasizing the importance of increasing the number of participating women in such endeavors (Westermann et al., 2005).

With resilience being key to coping with the changing climate patterns, stakeholders' adaptation capacity is determined by adopting technologies and/or improving of management practices (Torres et al., 2005). Roughly 77% of smallholder farms in low- and middle-income countries deal with water deficits. In light of rising complexities within food and water systems and an uncertain future, knowledge and technology are vital catalysts for transitioning from isolated organizational structures to thriving systems that adeptly balance synergies and trade-offs to meet commercial (Auguste & Bricker, 2007), political, and scientific objectives (Barrett et al., 2023). Studies conducted in developing countries consistently highlight gender differences in adaptive capacity. (Dev & Manolo IV, 2023; Kristjanson et al., 2019; Saravia Matus et al. 2022). Access to information emerges as a linchpin in building capacities and adapting to climate change, with variations in men's and women's information needs, access, and sources becoming apparent. (Kristjanson et al., 2019; Westermann et al., 2005; UN Women, 2023).

Reflecting on gender distribution in agricultural enterprises, women's ownership in Argentina is 21% on average, slightly exceeding numbers in Uruguay (20%) and Brazil (19%) but lagging behind Australia (22%), United States (24%), France (27%) and Spain (30%). This disparity is even more pronounced in Mendoza province, where only 18.9% of agricultural producers are women. Out of the 34,728 women associated with agriculture in Mendoza, only 1,758 (5.1 %) of them are producers or owners in a strict sense (based on INDEC, 2018).

The existing gender imbalance exacerbated by the current climate change projections could potentially deepen the socioeconomic inequalities if the access for women to resources and capacity-building remains limited (Njuki et al., 2023; Kristjanson et al., 2017; Huyer, 2016; Dev & Manalo IV, 2023). Women, in general, are more prone to identify necessary changes in food systems (Serpossian et al. 2022; Glazebrook et al., 2020). Empowering women in agriculture is associated with improved land productivity and a reduction in the average yield gap relative to their male counterparts (Njuki et al., 2023; Kristjanson et al., 2017; Huyer, 2016), spanning between 7.6 and 17.4% (FAO, 2023). Furthermore, the wage gap in the agricultural sector in Argentina is the most substantial(34.5%) across all economic activities in 2022 (DNEIyG, 2022), significantly surpassing the global agricultural wage gap of 18.4% (FAO, 2023).

Recognizing the need for a more comprehensive approach to address inequalities stemming from structural barriers, power dynamics, and non-inclusive decision-making processes, water governance principles have evolved. Effective water governance requires de-centralised planning and management in dialogue with affected stakeholders (Jagerskog, 2014). Data on participation in water management and decision-making disaggregated by gender and age is lacking (Saravia Matus et al., 2016). This not only neglects the critical importance of gender-sensitive policy design but also avoids an intersectional approach to climate change, water management and agricultural food systems (Aguilar Revelo,2021; Barrett et al., 2022; FAO, 2023; IFPRI, 2022).

In Latin America and the Caribbean, only seven countries specifically consider women's participation in water-related legislation and policies (Saravia Matus et al., 2016; Fletscher, 2009).In Argentina, female participation is very low across all water sectors, with no specific mention of women's involvement in legal frameworks (GLAADS, 2022). Despite recent efforts by the DGI to increase women's visibility, participation, and voices in the decision-making processes[1], only 34 women hold positions in the water inspections and only three female inspectors among the 138 positions in the province. There is only one woman with the responsibility of capturing and distributing the water among 396 *tomeros*[2] positions in the province. Their job is to monitor the irrigation network under their surveillance, matching the needs of irrigators with infrastructure conditions. Women possess invaluable knowledge about the location and quality of water resources. Yet, their knowledge remains untapped, and the inclusion of women in decision-making power regarding water development and management at all levels continues to lag behind (WWAP, 2015). Empowering women emerges as a key strategy to enhance the capacity to cope with the future consequences of climate change (Anderson & Sriram, 2019; Glazebrook et al., 2020). Participatory frameworks and an understanding of different approaches

[1] The ongoing program 'Agua y Mujer' seeks to empower women's participation and representativeness in water management and economic activities.

[2] This is a relevant water distribution position as their job is to monitor the water distribution subsystem, receiving and observing the needs of the irrigators while checking the operation of the gates, verifying the cleanliness of quotas and distributing the shift tickets.

to information needs are essential elements for enabling agricultural actors to build up their capacities. (Dev & Manolo IV, 2023; Quisumbing et al., 2023; Agarwal, 2000; Imburglia et al., 2021).

Data and methods

Data

Water institution in Mendoza province acknowledges the need for continuous capacity building to their technical and management staff. Therefore, an academic program was developed that targeted water institutions and included water users, agricultural producers, and local stakeholders. We collected data from two groups participating in the capacity-building program on Integral Management of Rural and Irrigation Organizations offered by the DGI in southern Mendoza, Argentina, in 2019. One group was located at the Diamante, while the other was in the Atuel River basin. The survey was conducted on a voluntary basis among attendees of the lecture. Data collection occurred through a digital platform, with a focus on exploring relationships, interactions, and information exchange among stakeholders. As water management networks have specific bonds from daily activities we expected that some participants would know each other before. This question was introduced with the objective of discovering the centrality of agents, measuring the openness of the network and assessing trust interactions. The primary goal of the survey was to determine whether participants were familiar with each other before the workshop and to identify the individuals with whom they engaged in conversations during the event.

To achieve this, the workshop participants were provided with a list of fellow participants. They were asked to indicate those they were already acquainted with before the workshop and those they only got to know during the event. Additionally, participants were queried about the topics they discussed during the workshop with other participants. To specify these discussions, five distinct topics were inquired about: water distribution, irrigation practices, input prices, market prospects, and climate contingencies.

Besides gathering data on relationships and conversation partners, we collected information on five social capital variables, including broader networks and trust (Table 1). These social capital variables were measured using a 7-point Likert scale, ranging from 1 ("completely disagree") to 7 ("completely agree"). While we collected complete information on both groups' knowledge and conversation ties, unfortunately, not all workshop attendees responded to the questions regarding social capital.Meanwhile,39% of the Atuel participants responded, and a higher proportion of 50% participated in the survey in Diamante. Nevertheless, caution must be exercised in interpreting the social capital results due to the notably low response rates. Acknowledging the likelihood of self-selection bias is essential , as only participants with a genuine desire to respond may have done so. This issue should be verified and addressed in future research endeavors. Regarding average scores, both groups

exhibited similarities in most social capital variables, except for *trust2* (positive future perspectives), where Diamante expressed a higher level of trust in a positive future compared to Atuel, which leaned towards disagreement or a neutral stance. However, both groups shared similar levels of trust in irrigators (*trust1*).Both groups remained relatively neutral when describing their knowledge of other producers (*net1*), on average, but maintained regular contact with DGI personnel (*net2*) during their attendance in the workshop. Neither group had close contact with input suppliers (*net3*), with Diamante respondents expressing disagreement on average and Atuel respondents leaning towards a somewhat disagreeable position.

Table 1. Means of social capital variables for both groups in Atuel and Diamante and disaggregated by gender. The number of responses to the single questions is indicated in parentheses.

Measure	Variable	Atuel (N = 28)			Diamante (N = 38)		
		Group	Women (N = 9)	Men (N = 19	Group	Women (N = 11)	Men (N = 27)
net1	I have good knowledge of producers	4.18 (11)	4.50 (6)	3.80 (5)	3.89 (18)	3.57 (7)	4.08 (11)
net2	I hold permanent contact with DGI staff	4.82 (11)	3.67 (6)	6.20 (5)	4.63 (18)	3.86 (7)	5.08 (11)
net3	I have fluid contact with agricultural input suppliers	2.09 (11)	2.50 (6)	1.60 (5)	3.05 (17)	3.43 (7)	2.83 (10)
trust1	Irrigators respect their assigned schedule	4.55 (9)	5.17 (5)	3.80 (4)	4.68 (18)	4.57 (7)	4.75 (11)
trust2	I have good perspectives of production clusters	3.55 (8)	3.17 (4)	4.00 (4)	4.63 (18)	6.00 (7)	3.83 (11)

To ensure privacy, we anonymized all workshop participants, thereby preventing any identification of individuals. However, we did differentiate between female and male participants in both workshops. In the Atuel group, there were 28 attendees, nine of whom were women (32.14%). The Diamante meeting had 38 participants, including eleven women, accounting for 28.95%.

Although the two groups tended to agree on average concerning trust and broader network connections, notable differences emerged between genders. In both groups, over 60% of women responded to the social capital questions (67% in Atuel and 64% in Diamante), while in Atuel, only 47%, and in Diamante, 44% of men answered. In Atuel, women tended to hold a neutral position regarding *net2*, placing them below the overall average. While men in Atuel exhibited a greater tendency to maintain contact with DGI employees. Additionally, there were contrasting responses regarding *trust1*, where women expressed more trust in irrigators, while men adopted a more neutral standpoint. The distribution of participants in Diamante was similar to Atuel concerning *net2*. However, in Diamante, participating women displayed greater confidence in future developments (*trust2*), whereas men remained more neutral. This is where the women in Diamante differed the most from their counterparts in Atuel.

Method

Capacity-building activities conducted in closed group settings contribute significantly to fostering relationships and facilitating unique group dynamics and structures for interaction (Faulkner & Nkwake, 2017; Lin et al., 2021; Esparcia & Serrano, 2016; Hermans et al., 2017). Social networksare valuable tools for accurately representing and analyzing these interactions, using nodes and links to depict relationships between individuals. The advantage of SNA, compared to many other methods, is that it focuses on relationships and connections between individuals and other group members. The positioning of a person within a group can provide information about mutual influence, e.g. when setting topics and priorities in the group context. But also whether and how topics are taken up. Therefore, It is not only individual resources, access to assets or human capital that determine how people act, but also their relations and ties within social structures. SNA is the tool to reveal and visualize such relations and for analyzing them (Jackson, 2008; Easley & Kleinberg, 2010; Borgatti et al., 2018; Lin et al., 2021; Esparcia & Serrano, 2016; Hermans et al., 2017; Bodin & Crona, 2009).

In social networks, nodes represent individual actors, while links illustrate their connections. These links can be either directed or undirected, depending on the nature of the relationship. Various characteristics are utilized for analyzing social networks. This paper focuses on several key measures, including density, degree, as well as in- and out-degree, centrality, shortest path, and reciprocity. Additionally, we identify hubs and authorities, such as brokerage, at the individual level.

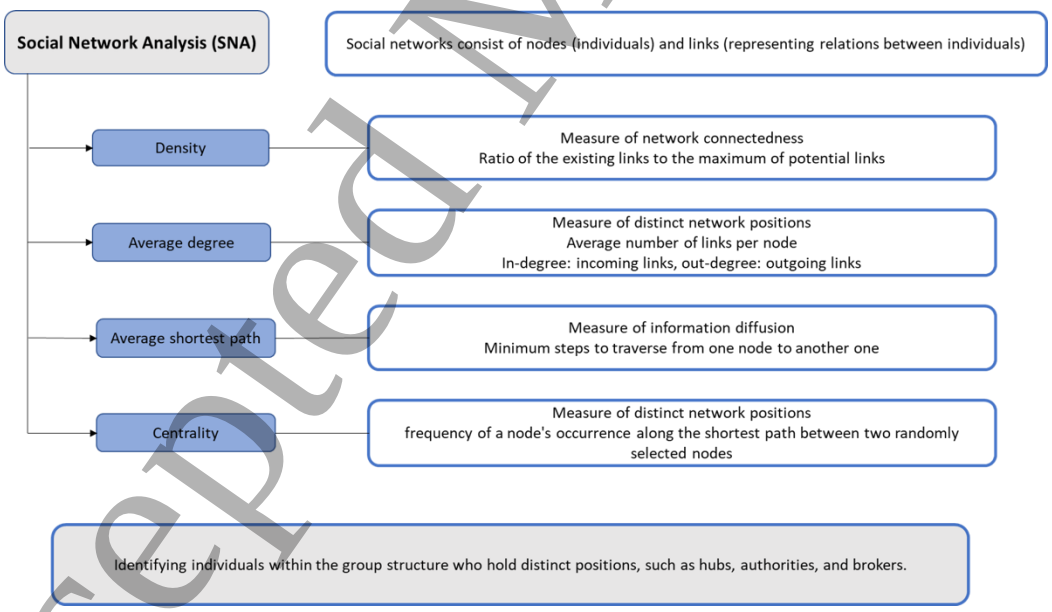

Figure 1: Measurable outcomes of SNA

Density, calculated as the proportion of actual links to the maximum possible number of links, reflects the connectedness of a network and ranges between 0 and 1 (Jackson, 2008; Easley & Kleinberg, 2010).

A density of 0 indicates a disconnected network, while 1 signifies a complete network where every node is linked to all others.

The average degree, measured at the network level, indicates the number of links per node and provides insights into the overall connectivity of the network (Jackson, 2008; Easley & Kleinberg, 2010). In directed networks, at the individual node level, we differentiate between in-degree (the number of incoming links) and out-degree (the number of outgoing links) (Jackson, 2008; Easley & Kleinberg, 2010). High in-degree is often associated with trustworthiness and prestige, while high out-degree can be a proxy for evaluating a person's influence or prestige (Valente et al., 2015; Borgatti et al., 2018; Jäckering et al., 2019).

The average shortest path measures the minimum number of steps required to reach one node from another in the network (Jackson, 2008; Easley & Kleinberg, 2010). It can provide valuable insights into how information spreads within a group. Centrality, another network-level characteristic, can be assessed using betweenness centrality, which measures how frequently a particular node falls along the shortest path between two randomly chosen nodes (Jackson, 2008; Easley & Kleinberg, 2010). This measure ranges between 0 and 1 and can help identify central individuals who may control and filter information within the group and act as gatekeepers (Valente & Davis, 1999; Montanari & Saberi, 2010; Borgatti et al., 2018; Ramirez et al., 2018).

Additionally, the identification of communities within a network based on betweenness centrality is crucial. Communities consist of nodes that are well-connected internally but have sparse connections to nodes in other communities (Newman, 2006). Broker nodes often facilitate community connections (Easley & Kleinberg, 2010; Abbasi et al., 2011; Scott, 2013). On an individual level, we also identify hubs and authorities. Hubs are nodes with high out-degrees, acting as potential information flow bottlenecks (Bodin & Crona, 2011; Scott, 2013). Authorities are individuals with high in-degree who are connected to hubs (Kleinberg, 1999).

We employ network graphs to analyze the network structures and differentiate between pre-existing and emerging links within both groups. Furthermore, we compute and display network characteristics for each of the five conversation topics covered in the questionnaire. Identifying central individuals becomes a focal point for understanding the dissemination of specific information within the groups.

Lastly, we incorporate data on social capital and associate it with the respective individuals within the networks. By relating the networks to the outcomes of previous analyses, we aim to explore the connection between social capital and network characteristics. Throughout this paper, we distinguish between female and male participants in both groups to uncover potential gender-specific patterns.

Results

Network characteristics

At the group level, we initially compare existing relationships before and after the workshop (Figure 2). In the Atuel group, Table 2 reveals that only three people (10.71%) were previously unknown to at least one other participant. Following the workshop, only one person remains unintegrated. The number of links increased by almost 36% during the meeting. However, the average degree slightly rises from 5.12 to 6.44 contacts after the workshop. The differences between the two genders show that they start with an almost even ratio before the workshop. Women, while representing less than one-third of the group, hold nearly 44% of the pre-existing links. During the workshop, however, it is mainly the men who make new connections (61% of the links after the workshop, or an increase from 36 pre-existing links to 53 after the workshop). The decrease in centrality and shortest path suggests that specific network agents can disseminate information more quickly and are less controlled.

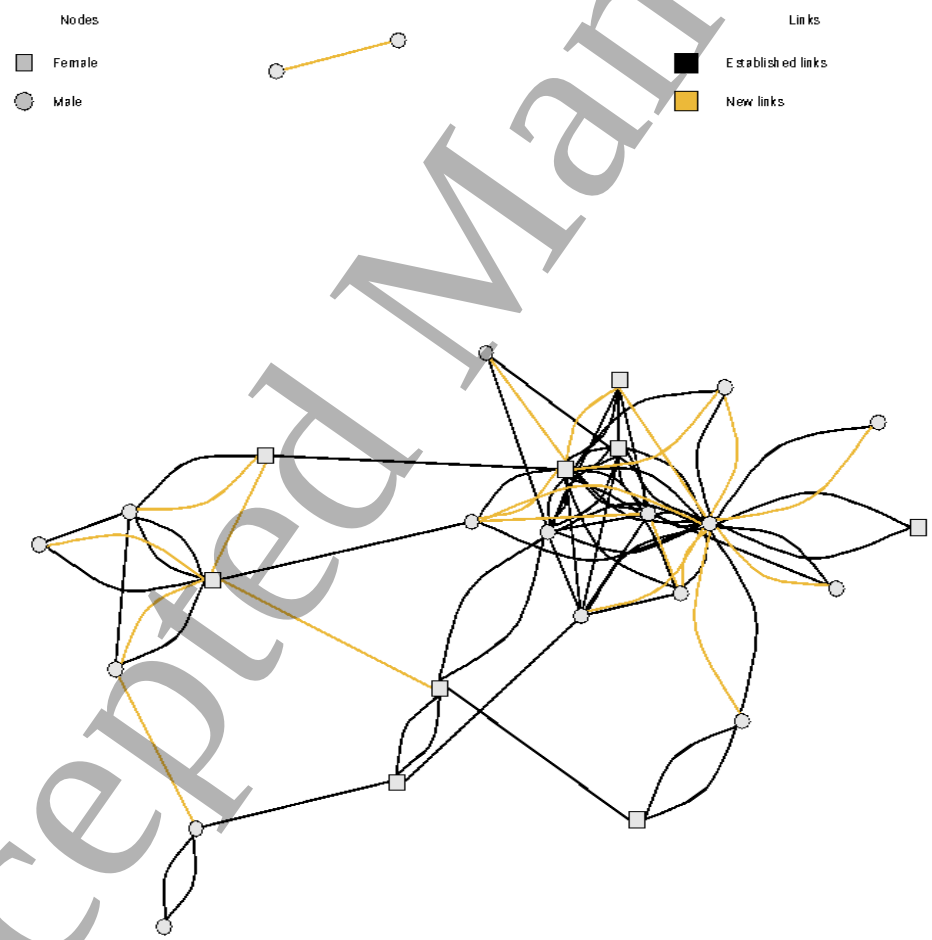

Figure 2. Pre-existing and new links in the Atuel group

In our second group in Diamante (Figure 3), only one additional person becomes integrated into pre-existing relationships during the meeting. In contrast, almost 13% of the participants (five people)

remain isolated (Table 2). However, there is an emergence of 44 newer links, representing an increase of nearly 42%. Here again, the men show a greater increase in new connections. Seventy-two acquaintances before the workshop become 110 afterwards. Women, on the other hand, can only make six new connections. The number of nodes remains relatively stable, but there is a significant rise in the average degree, with an additional 2.5 contacts per person. This implies a denser network with more links present, although not to the same extent as in the Atuel group. There is a noticeable reduction in centrality and the shortest path.

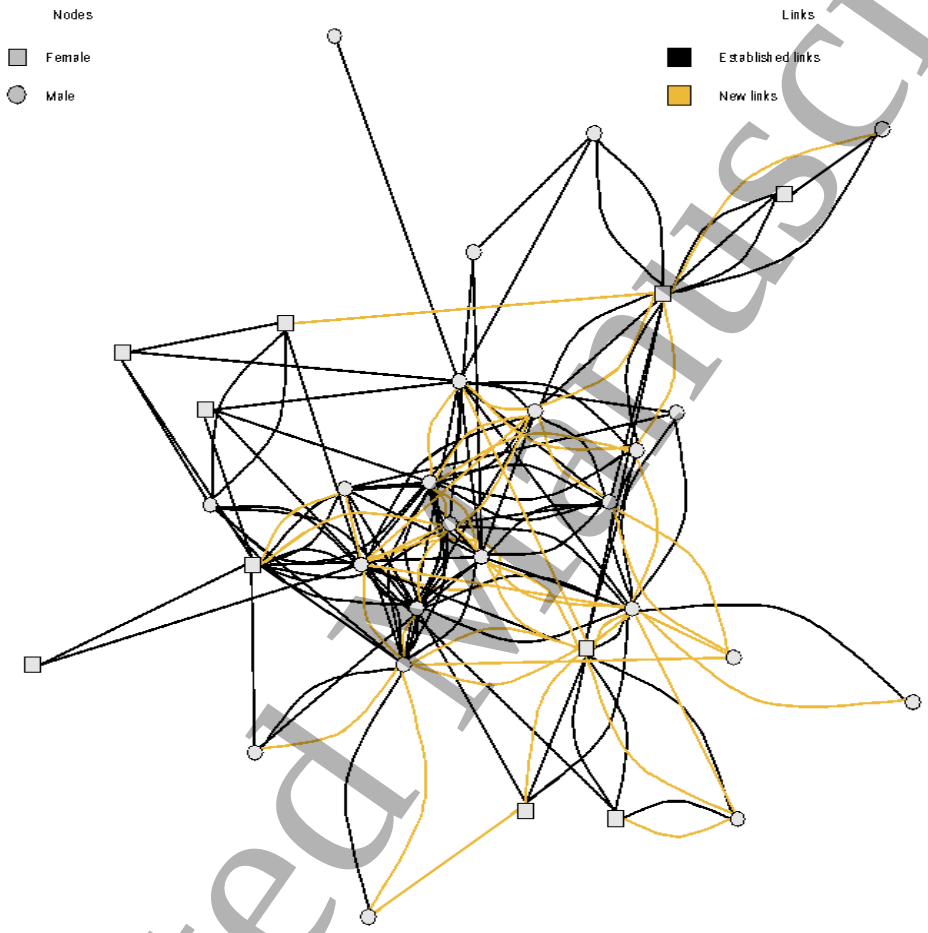

Figure 3. Pre-existing and new links in the Diamante group

When specifying the analysis according to the five sub-topics, participants in both the Atuel and Diamante groups used pre-existing links primarily discussing water distribution. Less-discussed topics included irrigation practices in Atuel and input prices in Diamante. By far most conversations about input prices and market prospects occurred along pre-existing links, indicating that trust plays a role in discussing sensitive economic matters. In Diamante, people were more inclined to form new connections to discuss climate contingencies. This suggests a higher willingness to interact with new individuals compared to the Atuel group. Surprisingly, while pre-existing relationships were used to discuss access to water, they were not utilized to discuss its efficient use. Overall, the study highlights

the role of trust in discussing economic matters, the varying preferences for conversation topics, and the distinction between shared interests and potentially private decisions within networked groups.

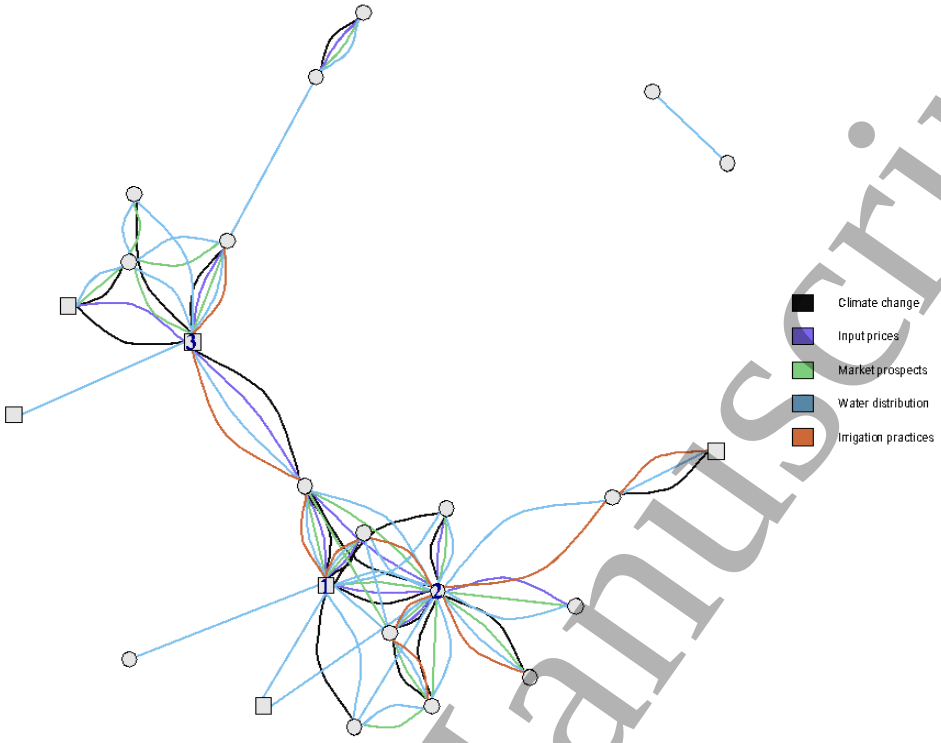

Figure 4.Topic networks in Atuel group

In the next step, we evaluate the network characteristics of the five different conversation topics in both groups. We present the merged non-directed networks as graphs in Figure 3 and Figure 4 and summarize the characteristics in Table 3. For more detailed, separate, and directed networks, please refer to Annex I. *Water distribution* is the most frequently discussed issue, with the highest number of links in both groups (42 in Atuel and 57 in Diamante). However, in the Atuel group, all except one node are involved, while in Diamante, 24 out of 38 people participate in conversations about water distribution. The topics with the highest involvement of people in Diamante are *market prospects* and *irrigation practices*. *Water distribution* has the highest average degree (3.5 in Atuel and 4.75 in Diamante).

In Atuel, the least number of people engage in talks about *irrigation practices* and *input prices*. The low centrality indicates that the networks for these specific topics are fragmented into several components. The number of communities further supports this fragmentation. In Diamante, fewer people discuss *input prices*. Regarding communities, both groups exhibit different results. Atuel distinguishes up to five communities in the *climate contingencies* and *input prices* network, while up to 14 communities can be detected in the *irrigation practice* network in Diamante.

Furthermore, there are other variations in network characteristics between the two groups. The average shortest path within the Atuel group is relatively fast, with only a one-node difference between *water distribution* (2.47) and *climate contingencies* (1.47). On the other hand, the average shortest path in the three networks of the Diamante group is higher than that in the Atuel group. Additionally, the disparity between the lowest value (*input prices*, 1.33) and the highest value (*market prospects*, 3.39) exceeds two nodes, indicating that it takes relatively more time for information on *market prospects* to spread compared *to input prices*.

Reciprocity, as a measure of the probability of reciprocal links in a directed network, is highest in the *irrigation practice* network for the Atuel group (0.571). Not only do fewer people participate in this topic, but the conversations predominantly occur between pairs of individuals. However, in the Diamante group, the network with the most links, *water distribution*, also exhibits the highest probability of reciprocity.

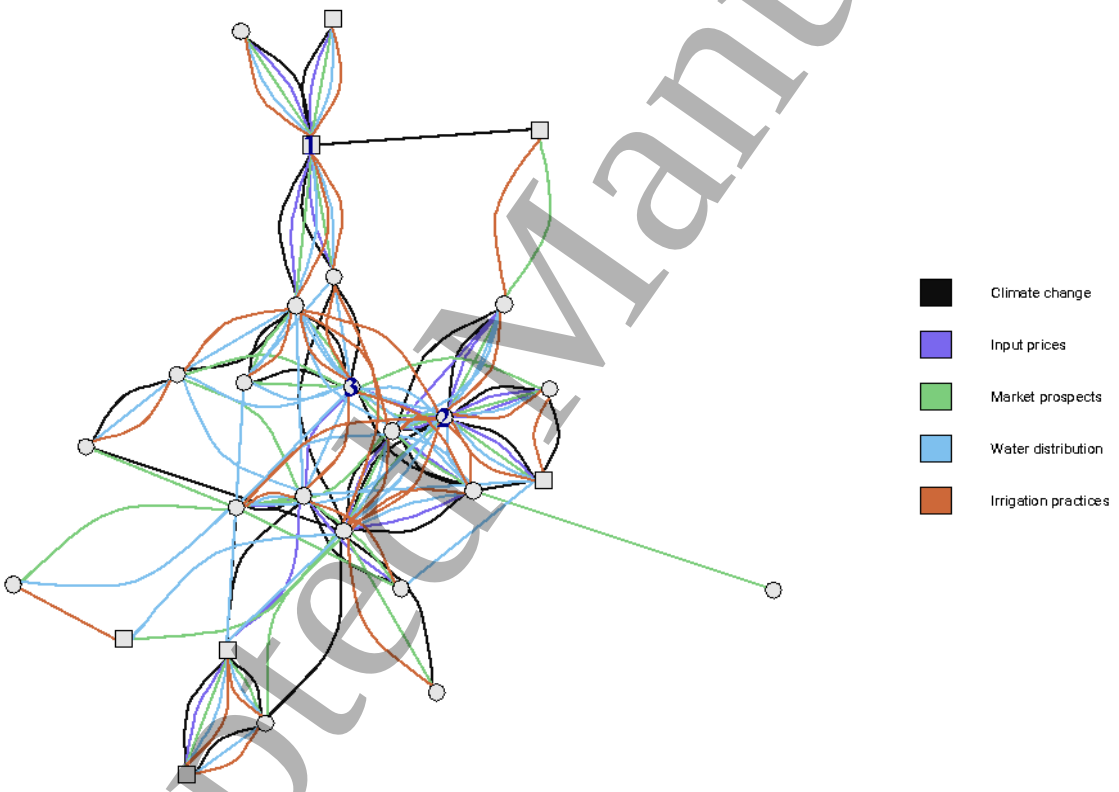

Figure 5. Topic networks in Diamante group

We can gain deeper insights into group dynamics if we examine the distribution among genders again. In Atuel, male participants notably hold a significant share in conversations concerning *water distributions* (78.6% of the links) and *market prospects* (78.3%). However, discussions about *input prices* are relatively balanced, with women contributing 46% of the links and men 54%. Similarly, exchanges regarding *climate contingencies* are divided, with women accounting for 45% of the links and men for 55%. Regardless of the topic, men are generally more popular conversation partners by

both genders. Regarding *market prospects* and *irrigation practices*, women exclusively engage with men and do not actively seek exchanges with other female participants. Out of the nine women attending the workshop, only two are actively discussing all five topics. While the majority of women are engaged in conversations regarding *water distribution*, they express their perspectives on *climate contingencies* with a broader range of eight partners. In contrast, when it comes to *irrigation practices*, they interact with only four partners to share their thoughts.

Table 2. Network characteristics for both groups with pre-existing links before and emerging links after the workshop

Group	Network	Nodes	Links	Isolates	Density	Average degree	Average centrality	Average shortest path
Atuel	Before workshop	25	64	3	0.213	5.12	0.074	2.71
	After workshop	27	87	1	0.248	6.44	0.049	2.42
Diamante	Before workshop	32	105	5	0.211	6.56	0.042	2.25
	After workshop	33	149	4	0.282	9.03	0.036	2.13

In Diamante, a more pronounced manifestation of the initial trend becomes apparent. Men consistently dominate discussions across all topics significantly, comprising 76% to 84% of the links. However, there are notable variations in dialogue partners. Women tend to engage in *climate contingency* talks primarily with other women, accounting for three out of four links. Conversely, there is once again a clear preference for male discussion partners when it comes to all other topics. Among the participants in the workshop, four out of eleven women actively participate in discussions on all the topics. In general, women are primarily involved in conversations about *irrigation practices* and *water distribution*, with a substantial majority of eight counterparts engaged in these exchanges.

Network positions

In addition to the characteristics of a network, understanding the positions of individuals within the network can provide valuable insights into how a group functions. In the case of directed networks, we can differentiate between popular and influential individuals by examining their in-degree and out-degree, which indicate their popularity or influence within the network (Hermans et al., 2016). These

individuals play a crucial role in the flow of information within the network, as they can filter and control the information. Therefore, when it comes to circulating specific pieces of information within a group, identifying such individuals within the group dynamics becomes significantly essential.

A person with a large number of outgoing links (high out-degree) is known as a "hub" and holds a significant role in the spread of information and in determining the type of information circulating within the group. An individual with a high number of incoming links from hubs is referred to as an "authority," as they collect information and possess the ability to assess its quality. Another significant position within the network is that of a "broker." Brokers connect different network components that would otherwise remain unconnected and separate (Easley and Kleinberg, 2010; Abbasi et al., 2011; Scott, 2013; Lin et al., 2021). The importance of a broker becomes evident in the *market prospects* network of the Atuel group. Without a broker node connecting the two components, both remain isolated, hindering the exchange of information and potentially limiting access to exclusive knowledge.

The topic networks in Atuel exhibit various structures, but all are divided into two or more components. A varying number of hubs can be identified, with the *water distribution* network being the largest, having seven hubs. In contrast, the other networks have fewer hubs (five in *climate contingencies* and three in the remaining networks). However, the number of authorities remains consistent at two, except in the *market prospect* network with three authority nodes. One individual (P21) holds an authoritative position in all networks and occupies a central role. Regarding the hubs, nodes P3 and P5 are the most relevant.

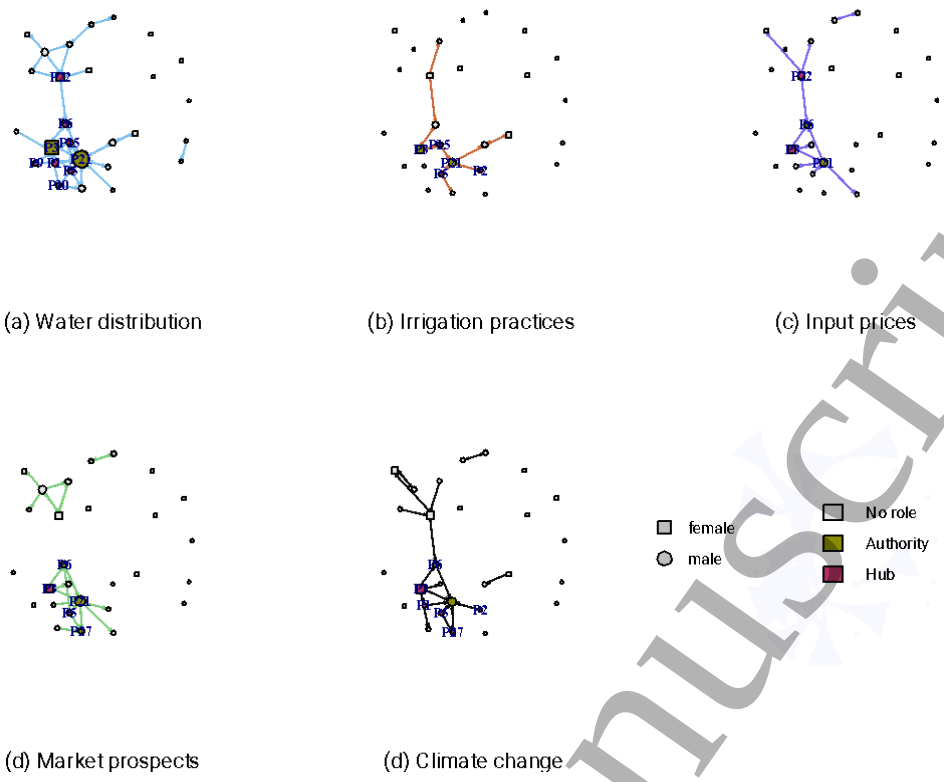

Figure 6. Network structures for the five topics, Atuel group

When considering the connections between components, we can identify at least one broker node and bridging link per network, except in the *market prospect* network. In the *water distribution* and *climate contingencies* networks, the link pointing from P22 to P6 is the only connection between the components. It is important to note that the recipient node also holds significant importance in addition to the broker node. In three out of four networks within the Atuel group, the same recipient node (P6) is present for bridging links in *water distribution*, *input prices*, and *climate contingencies*.

Despite their relatively low participation in the Atuel group, women play a crucial role in the network structure. Only around 32% of workshop attendees in Atuel are female, yet they occupy 36% of the hub positions (eight out of 22) and 18% of the authority positions (two out of eleven). This is particularly relevant regarding broker nodes, as three of the four broker nodes in the topic networks are female.

The Diamante group exhibits a different structure. All networks in this group are less fragmented but contain many isolated nodes and more separated communities, except the *water distribution* network. As there is usually one main component, only the *input prices* and *market prospects* networks have two brokers each. In the *input price* network, P10 links the two components using P11 as an intermediary node, and a similar configuration is observed with P19 connecting the two components in the *market prospects* network, with P24 acting as the intermediary node. In contrast to the Atuel group, the Diamante group shows more variation in the number of people occupying significant positions. Only P24 remains a hub in all networks, and P25 serves as an authority node in all networks except *climate*

contingencies. Another distinction from the Atuel group is that, despite the greater fluctuation in important network positions, most nodes in important positions in the Diamante group are male. Only three out of 35 hubs (8.6%) and two out of 18 authority positions (11%) are occupied by female participants.

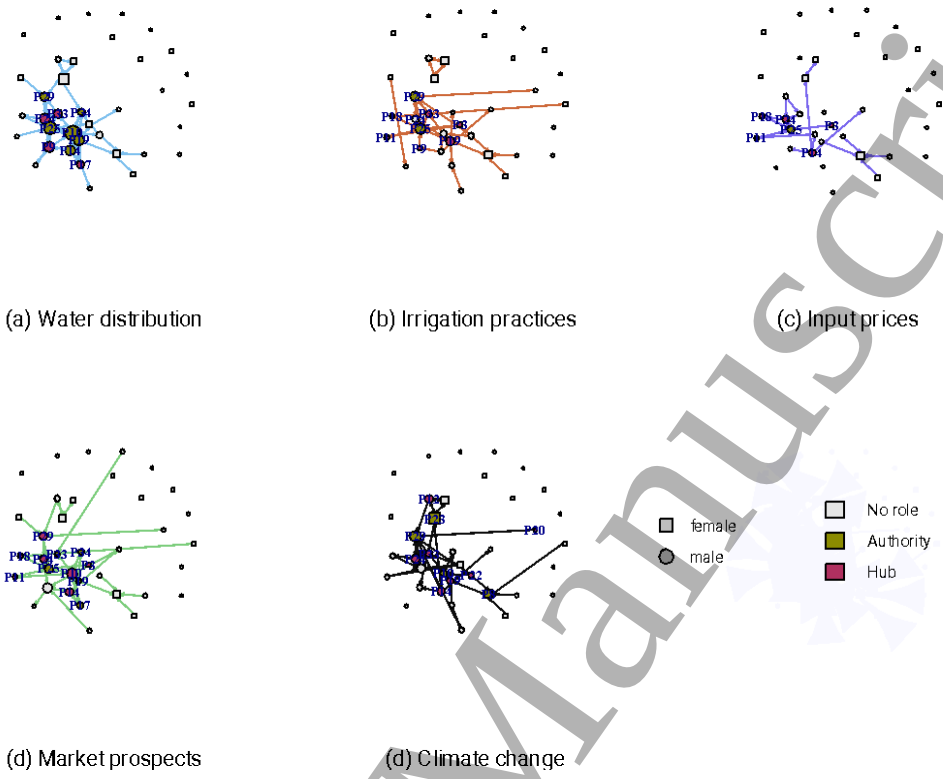

Figure 7. Network structures for the five topics, Diamante group

Our analysis of selected network positions demonstrates that groups can exhibit different structures. While the Atuel group is organized around a limited number of influential individuals, the Diamante group shows more variation. Concentrating on selected individuals within a group can have positive and negative effects. These individuals have the power to control and filter the flow of information, which can either restrict access to information for other participants or enhance the quality of information, depending on their agendas. Empowering women in the agricultural sector and encouraging their participation in farmers' associations and extension programs can facilitate the spread of information, as evidenced in the Atuel group. Therefore, not only the group structure but also the formation of the group itself plays a vital role in achieving coherence and interconnectivity.

Table 3. Characteristics for five topic networks in both groups

Group	Network	Nodes	Links	Isolates	Communities	Density	Average degree	Average centrality	Average shortest path	Reciprocity
Atuel	Water distribution	24	42	4	4	0.076	3.50	0.044	2.47	0.429
	Irrigation practice	11	14	17	3	0.126	2.55	0.107	2.36	0.571
	Input prices	12	13	16	5	0.098	2.17	0.017	1.50	0.308
	Market prospects	17	23	11	3	0.085	2.71	0.013	1.60	0.435
	Climate contingencies	18	20	10	5	0.065	2.22	0.006	1.47	0.200
Diamante	Water distribution	24	57	14	2	0.103	4.75	0.116	2.92	0.526
	Irrigation practice	26	37	12	14	0.057	2.85	0.009	1.91	0.222
	Input prices	18	20	20	3	0.065	2.22	0.004	1.33	0.105
	Market prospects	27	38	11	8	0.054	2.81	0.049	3.39	0.368
	Climate contingencies	24	42	14	9	0.076	3.50	0.015	1.91	0.333

Networks and social capital

Lastly, we analyze the relationship between network structures and respondents' outcomes on social capital. The detailed network diagrams can be found in Annex II. We distinguish between three variables in the individual network and two variables concerning trust towards stakeholders in the agricultural sector (see Table 1). As emphasized in the preceding data section, the low response rates to questions about individual social capital present challenges in interpreting results for both groups. Given these rates, a cautious interpretation of social capital results is essential, recognizing the potential for self-selection bias, where only participants with a strong inclination to respond may have participated, necessitating verification in future research. Consequently, making broader generalizations for the agricultural sector in Mendoza is currently impractical. However, specific notable findings deserve attention and warrant further investigation in future research endeavors.

The results indicate that in both groups the participants have the least frequent contact with input providers. This may explain why input prices are only discussed by a limited number of individuals. However, it is important to note that *input prices* and their fluctuations are crucial for farm planning and decision-making (Auguste & Bricker, 2017). Both groups demonstrate a high level of trust in irrigation institutions. *Water distribution* emerges as the main topic of conversation in both workshops, but it is not discussed in conjunction with *irrigation practices*. Notably, node P25 in the Diamante group appears to disagree with trust variable 2.

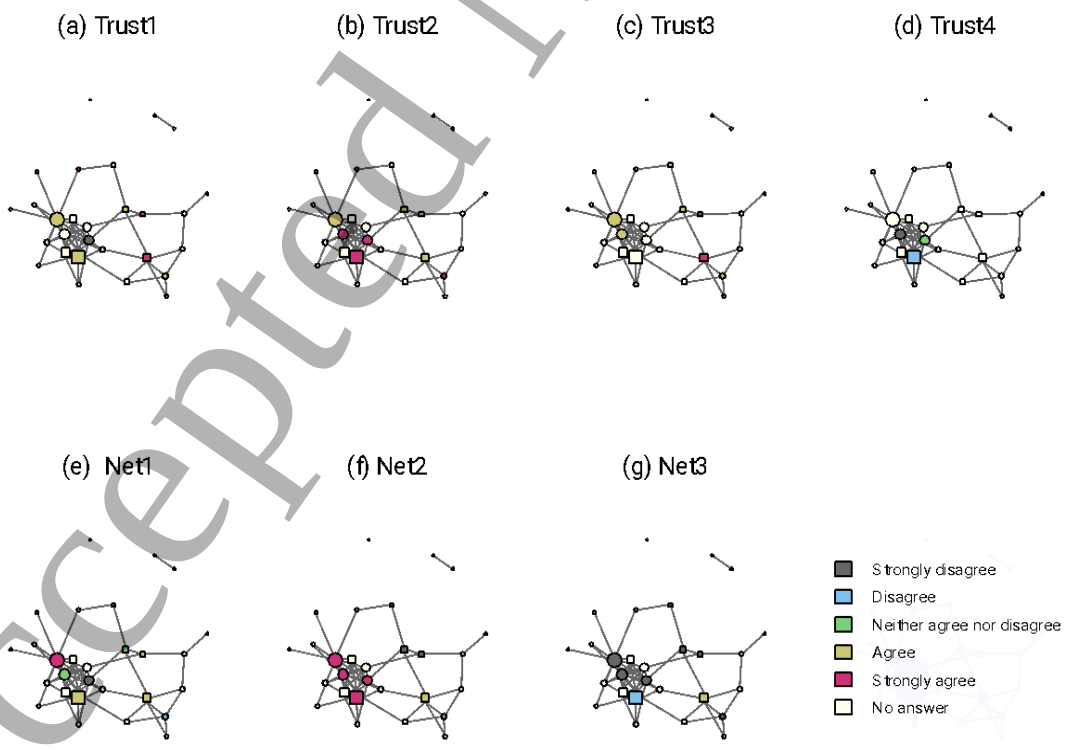

Figure 8. Network structures with variables on social capital, Atuel group

On the other hand, nodes P21 and P22 in the Atuel group express agreement without solid conviction, unlike node P3. These influential individuals play a crucial role in shaping the conversations. Although they are involved in discussions on *irrigation practices*, they do not disseminate information to as many people as they do for *water distribution*, for example. This observation could be attributed to their low trust or distrust of irrigation institutions, indicating their limited interest in discussing *irrigation practices*. Alternatively, they may not consider this topic essential or relevant within this group composition. It is important to highlight that in both groups, participants trust public institutions but do not perceive a strong bond among farmers. These findings contradict previous literature emphasizing that fellow farmers are typically seen as the most trustworthy source of information (Foster and Rosenzweig, 1995; Conley and Udry, 2010; Maertens, 2017; Sumane et al., 2017).

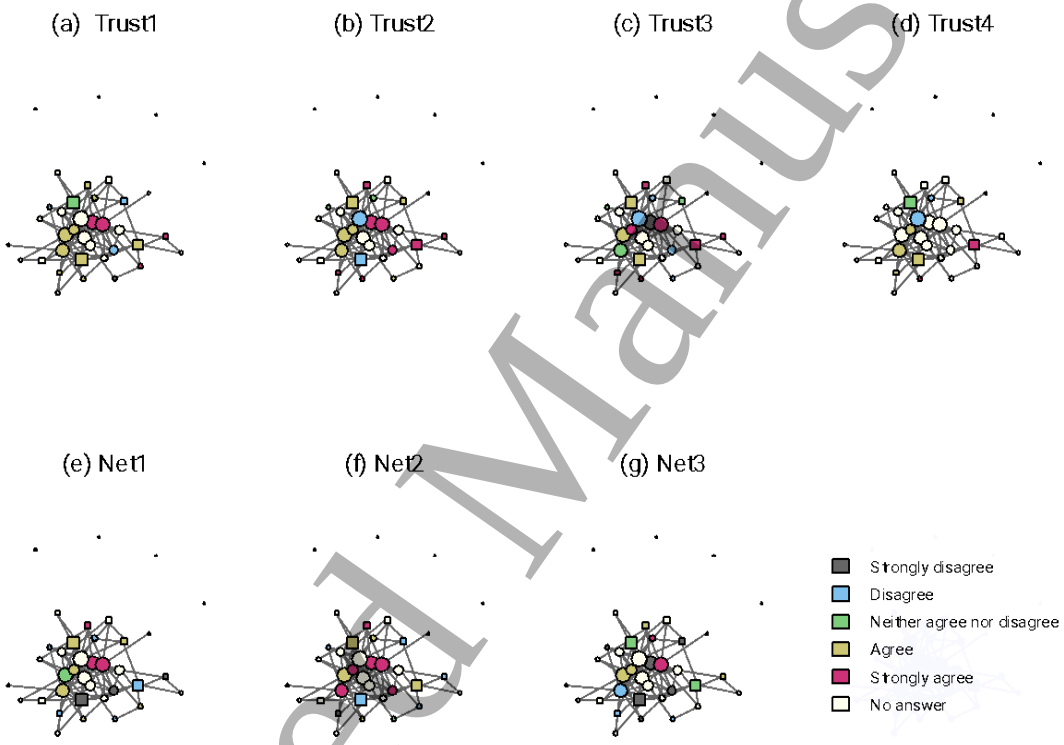

Figure 9. Network structures with variables on social capital, Diamante group

The identified nodes P3, P21, and P22 in the Atuel group are deemed crucial, exhibiting the highest agreement rates across all variables. All of their scores are substantially above the average for the group and above the average for their respective gender groups (compare Table 1).In the Diamante group, the results for node P25 vary, as it either disagrees (*trust2*) or does not respond. Node P10 demonstrates diverse levels of trust, with strong agreement for *trust1* and strong disagreement for *trust2*. Node P24 shows high approval rates for all trust variables. In the Atuel group, the individuals are considered trustworthy recipients and transmitters of information which is in line with their exhibit high levels of trust. This may explain why these three individuals hold critical positions across all network types. Conversely, the variation in trust levels among the three individuals in the Diamante group may explain why their expertise is only valued for specific topics and not universally across the network.

Discussion

The results of the social network analysis conducted on water and agricultural extension groups in Mendoza, Argentina, provide valuable insights into the dynamics of communication, gender roles, trust, and topic preferences within these groups. The following discussion will delve into the implications of these findings, drawing on relevant literature to contextualize and interpret the results.

One prominent observation is the gender-based differences in networking behavior. Men were found to be more active in establishing new connections within the groups, while women exhibited a more reticent approach. This finding aligns with previous research that highlights the existence of gender disparities in communication patterns (Eckert & McConnell-Ginet, 2003; Kristjanson et al., 2019; Glazebrook et al., 2020; Westermann et al., 2005). In the literature, women are observed to depend on informal networks within their social community, whereas men are commonly linked with formal sources of information and collaboration (Glazebrook et al., 2020; Westermann et al., 2005).However, the reasons are more of a structural nature than Intrinsic characteristics of women and men (Westermann et al., 2005; Huyer, 2016). W omen may face barriers that limit their participation and engagement in such spaces (Boellstorff et al., 2012; Anderson & Sriram, 2019; Quisumbing et al., 2023; Huyer, 2016).

Furthermore, the study reveals that men tend to be favored conversation partners across genders and topics. This resonates with the concept of gendered expertise, where men are often afforded more credibility and influence within knowledge-sharing environments (Buchanan et al., 2020). Social norms and entrenched gender roles often aggravate women from taking leadership and decision-making positions in groups (Quisumbing et al., 2023; Njuki et al., 2023; Agarwal, 2000). The bias towards male expertise might result from deeply ingrained gender biases that influence how individuals evaluate and attribute credibility (Brescoll & LaFrance, 2004).

Interestingly, despite the underrepresentation of women in the groups, they play a crucial role in the network structure. In the Atuel group, for instance, women hold a significant number of hub and authority positions, suggesting their central role in information dissemination and decision-making processes. This aligns with studies emphasizing the importance of women as information brokers and knowledge disseminators within social networks (Valente & Pumpuang, 2007). Literature consistently indicates that mixed groups featuring female participants often exhibit enhanced collaboration and conflict resolution skills (Westermann et al., 2005). The inclusion of women in crucial broker positions is particularly vital for ensuring group cohesion, thereby mitigating the potential disintegration of sub-groups(Easley and Kleinberg, 2010; Abbasi et al., 2011; Scott, 2013; Lin et al., 2021). Results show that women are trustworthy and often consulted on input prices, market expectations, and irrigation practices. Moreover, they disseminate information faster than men but should increase communication with their peers. Their role as hubs and authorities underscores the need to recognize and harness the

contributions of women to enhance the effectiveness of group communication (Agarwal, 2000; Esparcia & Serrano, 2016) that could increase the climate change adaptation by spreading the word and practices.

The importance of empowering women and encouraging their participation, as their involvement can facilitate information spread and strengthen group coherence. This aligns with broader discussions about gender inclusivity in decision-making processes and the value of diverse perspectives in problem-solving (UN Women, 2021). Nevertheless, extension services, climate change adaptation programs, and technological innovations remain gender-blind, perpetuating structural discrimination against women in the agricultural sector (Anderson & Sriram, 2019; Quisumbing et al., 2023; Huyer, 2016; Njuki et al., 2023).Strategies that promote gender equity and amplify women's voices could lead to more comprehensive and effective communication networks. Group membership and access to agricultural groups emerge as critical elements in empowering women in the agricultural sector (Njuki et al., 2023; Westermann et al., 2005). Women play a pivotal role in managing natural resources, supported by ample evidence demonstrating a positive relationship between women's engagement and environmental outcomes (Quisumbing et al., 2023; Anderson & Sriram, 2019; Agarwal, 2000).The role of trust emerges as a critical factor in shaping discussions within both groups. Trust influences participants' willingness to engage in conversations about sensitive topics, such as *input prices* and *market prospects*. The preference for interactions with familiar individuals underscores the role of trust in creating a safe and supportive environment for open communication. Trust has been identified as a key driver of information sharing within networks, with its absence potentially hindering knowledge exchange (Sicilia et al., 2019). Interestingly, the Atuel and Diamante groups display distinct trust dynamics among women. In the Atuel group, high agreement rates across trust variables underline women's considerable influence in shaping conversations. Conversely, trust levels among women in the Diamante group vary, potentially impacting their recognition as experts in specific topics. These differences highlight the need for a nuanced understanding of gender and trust dynamics within distinct social contexts. This could indicate a potential gap in knowledge sharing within the groups, prompting the need for targeted interventions or initiatives to promote conversations around irrigation practices.

Finally, the variation in discussion preferences across topics highlights the importance of tailoring communication strategies to address specific interests and concerns. While irrigation practices receive relatively less attention, discussions about climate contingencies seem to prompt a higher willingness to interact with new individuals. This is a remarkable take-away for capacity building as women are keener to incorporate adaptation practices while disseminating their knowledge throughout their networks. On the other hand, it represents a valuable insight for group facilitators and policymakers. This suggests that aligning communication efforts with pressing and relevant topics can facilitate engagement and knowledge sharing.

In both groups, discussions regarding climate change primarily involve a significant contribution from women. The literature provides evidence that women engaged in farming face heightened vulnerability

to climate shocks and extreme weather events compared to their male counterparts (Dev & Manolo IV, 2023; Kristjanson et al., 2019; Anderson & Sriram, 2019). Moreover, research suggests a positive correlation between women's involvement and environmental outcomes, with women exhibiting a greater propensity to adopt sustainable farming practices (Quisumbing et al., 2023; Anderson & Sriram, 2019; Agarwal, 2000). Therefore, women being involved in discussions around climate change might be a sign of empowerment as well as of understanding of the relevance of the issue

Empowering women is increasingly recognized as a pivotal strategy for enhancing the capacity to cope with the future consequences of climate change (Anderson & Sriram, 2019; Glazebrook et al., 2020). Participatory frameworks and an understanding of diverse approaches to information needs are deemed essential elements for enabling agricultural actors to strengthen their capacities (Dev & Manolo IV, 2023; Quisumbing et al., 2023; Agarwal, 2000). Additionally, recognizing that women have distinct requirements in terms of information, group behavior, and other issues is crucial.

Given that climate change stands as one of the most pressing challenges for global agriculture, it is imperative to include women in adaptation strategies. This inclusion should not only view women as victims of climate change but also as contributors of solutions and innovative approaches.

Conclusions

Building resilience is among the best institutional investments to combat the effects of climate change, improve agricultural water usage and governance of water institutions (Saravia Matus et al., 2022). Water is among the most critical production factors in semi-arid agricultural land and much dependent on resilient production and management systems. This research dive into communicational networks of local stakeholders in two irrigation basins of southern Mendoza Province to understand the existing information flow, map the interactions, and further analyze key persons as agents of change.

The social network analysis sheds light on the intricate interplay of gender, trust, expertise, and topic preferences within water and agricultural extension groups in Mendoza, Argentina. The findings underscore the need to address gender disparities, recognize women's contributions, and cultivate trust to foster effective communication networks. Furthermore, the study highlights the significance of adapting communication strategies to cater to specific topic interests and concerns. By acknowledging these dynamics, efforts can be directed towards creating inclusive and robust communication platforms that facilitate the exchange of knowledge and promote sustainable agricultural practices.

Information exchange is fluid and not limited to water management. Notwithstanding, social capital factors could further trigger higher levels of interaction supporting market and technical advice. Female participants are central in the conversations of market prospects and climate contingencies; however, not further consulted on water related issues. Building capacity on stakeholders significantly improves the interaction within the network, where water management is a topic-catalyzer giving room for

communications in other topics, in particular climate change, market related aspects but surprisingly not extensively for irrigation practices.

The social network of the Diamante basin showed a higher increase in average degree than the network of the Atuel basin indirectly implying higher connectivity among peers in a closed network. Diamante network had 1 popular node while Atuel network expressed 1 important broker node and 2 nodes in key positions for controlling and spreading information. Despite higher male representation in both networks, female participants were more active as communicational nodes.

Women's influence in shaping conversations is evident through their high agreement rates across trust variables. This suggests that their opinions and perspectives are influential in shaping group dynamics. However, trust levels among women in the Diamante group vary, impacting the recognition of their expertise for specific topics. The role of women in the network is remarkable as it is often consulted.

Inclusive and gender-oriented capacity building would further improve representativeness while broadening the information flow allowing stakeholders to receive relevant data on water management and its implications. As expected, *water distribution* is an abundant subject that brings people together for discussion but urgently calls for additional conversations regarding proper water usage, technology adoption and market linkages. Central nodes are perfect ingredients for disseminating right information and foster collaboration among peers, but these individuals need to be closely targeted and technically formed to become agents of change in the irrigation networks.

We conclude that capacity building activities multiply contacts within the network and provide room for increasing knowledge and discussion of critical aspects that normally remain undiscussed as irrigation practices.

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