Building ties at multi-stakeholder engagement events to facilitate social learning about contentious issues in natural resource management

Tian Guo, Sandra T. Marquart-Pyatt, G. Philip Robertson

Authors:

Tian Guo, Department of Human Dimensions of Natural Resources, Colorado State University, 222 W Laurel Street, Fort Collins, Colorado, 80521, US

Sandra T. Marquart-Pyatt Department of Geography, Environment and Spatial Sciences, Michigan State University, 673 Auditorium Road, East Lansing, Michigan, 48824, US; Department of Political Science, Michigan State University, S. Kedzie Hall, 368 Farm Lane, East Lansing Michigan 48823, US

G. Philip Robertson, W.K. Kellogg Biological Station, Michigan State University, 3700 E. Gull Lake Dr, Hickory Corners, Michigan 49060, US

ABSTRACT

Complex natural resources issues including sustainable agriculture require diverse stakeholders to take voluntary and even coordinated actions. Social learning is a critical process for stakeholders to navigate differences in knowledge, values, and ways of knowing while building trust and coordination capacity. Integrating the social learning approach along with social networks, well-proposed, well-designed, and effectively facilitated stakeholder engagement events can promote bridging and information exchange by capitalizing on stakeholder interests and formal and informal interaction opportunities. We collected survey data

before and after a stakeholder engagement event for a USDA Long-term Agroecosystem Research (LTAR) site in the summer of 2022. A total of 76 individuals participated in the event coming from diverse groups in the agricultural community, including representatives from agribusiness, extension, farm advisers, farmers, nonprofit organizations, state and federal agencies, and university-affiliated researchers and staff. We conducted two-mode network analyses for participant interests and evaluated connections with other stakeholder groups before and then again after the event. We also explored emerging information exchange ties along with the levels of similarity of these new ties. We found that participating stakeholder groups shared an interest in having greater connections to farmers. Many of the new connections were across affiliation groups and people with different views suggesting opportunities for information exchange. Results demonstrate the value of stakeholder engagement events based on stakeholder interests for facilitating the formation of bridging ties that support social learning.

Keywords: outreach and engagement; common experiment; multi-stakeholder initiatives

INTRODUCTION

Shared understanding and relationships are key to resolving intricate environmental problems in agriculture, such as nutrient pollution, biodiversity loss, and water scarcity. This is because different stakeholder groups need to take voluntary and even coordinated actions, such as producers adopting best land management practices, agencies and conservation organizations providing technical and financial support, agriculture professionals developing environmentally friendly inputs, and consumers demanding sustainable products (Reimer et al. 2018; Charnley et al. 2020; Amblard 2021). Sachet et al. (2021) highlighted the importance of trust between researchers and farmers to achieve agroecological transition. However, stakeholders often come to an issue with diverse beliefs, values, and ways of knowing (Neef and Neubert 2011).

45 Navigating the differences while building trust, enhancing coordination capacity, and fostering
46 positive relationships is a challenging yet critical step to tackling many agricultural challenges
47 (Muro and Jeffrey 2008; Jackson-Smith et al. 2018; Fernández-Giménez et al. 2019; Nikkels et
48 al. 2021; Buchecker et al. 2023)

49 Engaging stakeholders in research projects may help build shared understanding and
50 relationships through stimulating social interaction and the formation of social ties with
51 intentional design (Teodoro et al. 2021). The process of changing perceptions, relationships, and
52 even behaviors through sustained interactions is sometimes described as social learning. Cundill
53 and Rodela (2012) summarized "…the term has been used to refer to processes of ongoing
54 deliberation that take place through sustained interaction and trust building between
55 stakeholders, who expose their own values and share knowledge about the issue at stake". Reed
56 et al. (2010) defined social learning as "changes in understanding that go beyond the individual
57 to become situated within wider social units of communities of practice through social
58 interactions between actors within social networks". A social network consists of interacting
59 nodes (individuals or organizations) and the ties among them, such as shared similarities, social
60 relationships, and interactions (Bodin and Prell 2011; Kadushin 2012; S. B. Borgatti et al. 2013).
61 These ties allow for information exchanges and expose individuals to various values, beliefs, and
62 ways of knowing (Mostert et al. 2007; Luján Soto et al. 2021). Exposure to these ideas and
63 information, coupled with deliberation, discussion, and reflection, are key conditions for social
64 learning (Cundill and Rodela 2012).

65 The connections between social learning and changes in social networks have been noted
66 in the literature on stakeholder engagement. For example, Luján Soto et al. (2021) found that
67 participants in a participatory monitoring and evaluation program for innovative sustainable land

management strengthened and expanded their networks for information sharing. Participants showed a more complex and broader shared understanding of regenerative agriculture. Teodoro et al. (2021) studied networks of mutual understanding, respect, and influence among residents, scientists, and government officials who collaboratively manage the impact of sea-level rise. They found that these networks are positively associated with perceptions of climate change. Hoffman et al. (2015) found growers' participation in traditional outreach activities such as meetings and demonstrations is a strong predictor for their number of knowledge-sharing relationships. Building new relationships along with learning new knowledge and perspectives have also been recognized as benefits to participating stakeholders (Jackson-Smith et al. 2018; Holifield and Williams 2019).

More attention has been given to designing stakeholder engagement events for social learning, through the lens of social networks (Cundill and Rodela 2012; de Vente et al. 2016). Diversity and stakeholder representation are key design features (Neef and Neubert 2011; Reed et al. 2018; O'Connor et al. 2019). People tend to cluster with like-minded others in groups, a phenomenon known as homophily (McPherson et al., 2001). For instance, Barnes et al. (2022) found that naturally emergent networks in rural agrarian communities favor the inward strengthening of existing networks, while the ties to people with different resources and information did not increase. Fischer and Jasny (2017) found forest and wildfire management organizations in the West U.S. were inclined to associate with others with similar management goals and strategies, leading to more clustered network structures. To overcome the homophily tendency, convening stakeholders from different groups may allow for more perceptions to be represented at an event and stimulate the formation of ties across stakeholder groups. The ties between different stakeholder groups can be referred to as bridging ties, emphasizing interactions

that bridge individuals with varied affiliations, beliefs, values, and resources (Moody and Paxton 2009). Stakeholder engagement events may break the norm or tendency of interacting with similar people, fostering bridging ties.

Built on participant diversity, facilitated group discussions and unstructured social times can be incorporated into engagement events to encourage deliberation, exchange, and reflection. For example, Brymer et al. (2018) analyzed stakeholder dialogues across five workshops coordinated for habitat restoration. They found the discussion changed participants' views on ecosystem services, social processes, and the value and place meanings, among other outcomes. The workshops also stimulated opportunities for participants to stay connected and work together on other projects. Hoffman et al. (2015) found participants in traditional agriculture outreach activities (e.g., meetings and demonstrations) developed knowledge-sharing relationships. The role of facilitators in creating a safe environment for discussion and encouraging individuals to contribute has also been noted as important (de Vente et al. 2016; Sterling et al. 2017; O'Connor et al. 2019; Eaton et al. 2021; Wade et al. 2024). Wilmer et al. (2022) observed that in the early stage of a six-year Collaborative Adaptive Rangeland Management, the research team initially undervalued the importance of facilitation skills and collaborative methods, which led to confusion and tensions in early meetings with stakeholders. Their study also highlighted stakeholder engagement as an adaptive process that benefits from adjustment based on evaluation.

Incorporating interactive activities in stakeholder engagement events must consider the social context of the project including stakeholder characteristics and interests (Neef and Neubert 2011; Reed et al. 2018; Eaton et al. 2021). De Vente et al. (2016) found stakeholder analysis at the early stage of a project was correlated with outcomes such as information gain, learning by

participants, and trust between non-state actors and scientists. Skaalsveen et al. (2020) observed that the development of a network of no-till farmers in the U.K. was driven by individuals' ability and interests in communicating and learning from other farmers. Holifield and Williams (2019) found a lack of interest, along with a lack of time and awareness, was the major obstacle to recruiting and sustaining stakeholder participation. Hutchins et al. (2013) underscored the benefits of proactively assessing partnership potential and participant interests before forming partnerships. Understanding stakeholder interests in connecting with other groups can indicate the status of relationships among stakeholders (e.g., friendly or contentious) and how stakeholders may show up to interactive activities (e.g., open-minded or cautious). A conducive or contentious social environment for interactions will require different facilitation approaches and activities.

Figure 1 shows how we expect social networks to change for social learning in a stakeholder engagement event when the design incorporates interaction opportunities for diverse stakeholders and considers stakeholder interests. On the leftmost side of the diagram, we see individuals with particular group affiliations, all of whom are groups (marked by circles) in the agricultural community and bring unique insights to understand an issue such as sustainable agriculture. There are existing ties between individuals with different affiliations (marked by arrows) and individuals within the same affiliations. For the clarity of the graph, existing ties within a group are not depicted. The middle panel depicts designed activities at the event such as breakout discussion groups and lunch tables (marked by circles) and spontaneous network opportunities to allow for interactions (arrows). On the rightmost side of the diagram, in an ideal situation, new (bridging) ties are formed between groups, marked by thicker arrows, allowing changes in group dynamics and information sharing.

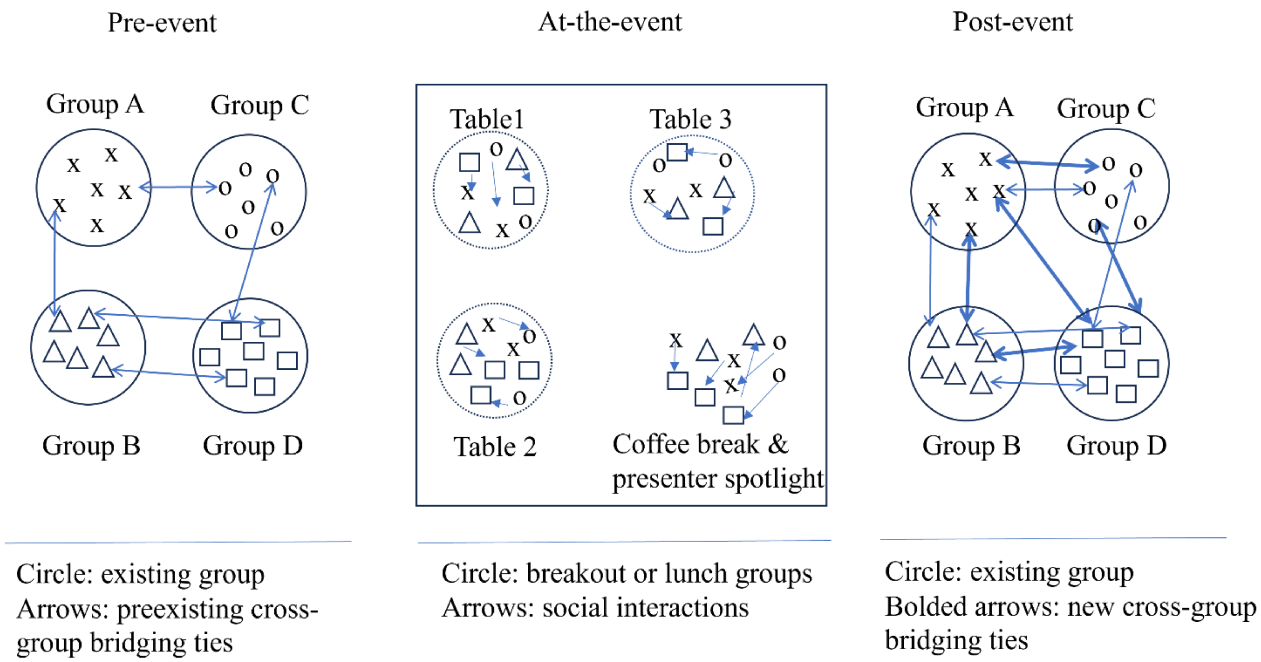


Figure 1. Conceptual depiction of network expansion through a hypothetical stakeholder engagement event.

Following this conceptual framework, we used social network analysis (SNA) to capture the interactions among stakeholder groups at a day-long event that included field demonstrations, presentations from scientists and stakeholders, and facilitated discussion. A pre-survey and a post-survey allowed us to observe three networks: individuals' initial interest in connecting with other groups (individual-group interest network), their connections with other groups post-event (individual-group realized network), and their information exchange ties with individuals after the event (individual-individual realized network). We hypothesize that interactions at a stakeholder engagement event will create new ties among different stakeholders. From these three networks, we analyzed:

(1) Patterns in participants' interests in forming ties with other groups of stakeholders and the ties with stakeholders from other groups

(2) The characteristics of information exchange ties formed at the event

(3) The impact of breakout group and stakeholder engagement on new information exchange ties

The study is part of the Kellogg Biological Station (KBS) Long-Term Agroecosystem Research (LTAR) project, one of the USDA's national LTAR network sites. The focus of LTAR network is to design agriculture that can meet the growing demand for agricultural commodities, protect environmental quality, and enhance life in rural and national communities. The network's vision, as outlined in its latest strategic plan, is to create a sustainable agricultural community that achieves production, environmental, and social goals (US Department of Agriculture, 2024). Social goals include human health (e.g., worker safety, flexibility, satisfaction) and social cohesion (equity, community security). Environmental goals focus on air quality, greenhouse gas mitigation, water and soil health, and biodiversity. Production goals emphasize commodity quality, productivity, water use efficiency, yield, and financial stability. The network examines various agroecosystems, including croplands, rangelands, and pasturelands.

KBS conducts Aspirational Cropping System Experiments (ACSE), comparing current practices (business as usual or BAU) with an aspirational (ASP) system aimed at economic prosperity and conservation benefits. The ASP system at KBS was developed through stakeholder engagement, including a 2021 visioning symposium with experts from academia, industry, non-profits, and agencies (Robertson et al., in review). Following the symposium, focus groups and a system design team consisting of farmers, crop advisers, and agronomists identified key principles: high crop diversity, circularity, year-round plant cover, continuous no-till, precision technology, prairie strips, and livestock integration. The ASP treatment includes

practices such as 5-crop rotation, continuous no-till, cover crops, precision fertilizer inputs, and integrated pest management.

MATERIALS & METHODS

Study Context

In 2022, a KBS LTAR stakeholder field day event was developed to support the design of KBS ACSE. The goals of the event are threefold: to build and strengthen relationships with existing and new partners, hear from partners on current context of midwestern farming and conservation, and receive advice on the KBS LTAR experiment plans. The field day features in-field visits and reflections, researcher presentations and field demonstrations, stakeholder presentations on policies and new technologies, and break-out discussions on aspects of agriculture outcomes, water quality, soil health, social well-being, and economic well-being. A stakeholder engagement specialist and project leaders jointly selected and invited participants for the field day to represent diverse stakeholder views. Key stakeholders included agribusiness, extension, farm advisers, farmers, nonprofit organizations, state and federal agencies, and university-affiliated researchers and staff. A total of 76 individuals participated in the 2022 KBS LTAR stakeholder field day.

To encourage interactions and begin the event with a welcoming tone, the stakeholder engagement specialist and researchers greeted participants at an outdoor tent set up next to the experimental fields. Coffee and breakfast were provided. During the day, participants rode on wagons to different fields to hear research highlights from KBS and reflections from partners. A few stakeholders were invited to present on the current context of agriculture and conservation. The outdoor setting allowed for more informal interactions between the audience and presenters, as well as among the audience members. Lunch was provided, accompanied by a presentation

from a social scientist on insights from the 2021 stakeholder scoping survey. After lunch, participants were divided into pre-defined groups to reflect on what they had heard and discuss indicators for sustainable agriculture. The stakeholder specialist facilitated the breakout discussion using guiding questions such as, “What do you want to know about these systems and why?”, “What hasn’t been discussed so far today that would be good to measure?”, and “Given what we heard from our partners, what else will be important to track and know about these systems?”. The event concluded with a happy hour featuring Michigan-sourced refreshments, offering another informal opportunity for interactions. We observed formal discussions during the breakout session and informal chats during breakfast, coffee breaks, lunch, happy hour, and on the wagon rides.

The KBS LTAR project is ongoing with a strong commitment to long-term stakeholder engagement. In 2023, an advisory board consisting of farmers, crop marketing organizations, conservationists from organizations, and policy influencers. The Board meets regularly to provide feedback and advice and help to distill input from the larger group of stakeholders into actionable goals. In addition, farm field days and workshops were held in 2023 and 2024 to provide sustained interactions between stakeholders and researchers and among stakeholders.

Data Collection: survey design

The data were from an online pre-survey, sent to participants of the event one month before the event, and an online post-survey sent one month after the event. The survey questions were designed in consultation with the project leadership team and stakeholder engagement specialist and based on previous literature on the effectiveness of stakeholder engagement (Jackson-Smith et al., 2018; Teodoro et al., 2021; de Vente et al., 2016; Eaton et al., 2021).

For questions related to networks, in the pre-event survey participants were asked to select all the groups they would be most interested in networking with at the field workshop (Network 1; Table 1). Respondents could select as many groups as they were interested in from a total of eight options including agribusiness, extension, farm advisor (e.g., agronomic consultant), farmers, non-profit organization, state/federal agency, university-affiliated researcher, and others. The question was repeated in the post-event survey, asking whether respondents met anyone new at the workshop and if so, which groups their new connections were from (Network 2; Table 1).

In the post-survey, we also asked respondents to list individuals they did not know before the June 2022 workshop but shared information with at the workshop (Network 3; Table 1). Other questions in the post-survey gauged participants' views on the proposed aspirational cropping system treatment, using a five-point semantic scale with five pairs of descriptions (ordinary to innovative, unprofitable to profitable, non-resilient to resilient, no additional environmental benefits to enhanced environmental benefits, and not easily managed by farmers to easily managed by farmers) (Question layout see Appendix).

Data Analyses

We analyzed three networks, including two two-mode networks (Network 1 and Network 2) and one individual-to-individual (peer-to-peer) network (Network 3; Table 1). Analysis methods were selected based on the two types of network data that were collected. For Network 1 and Network 2, the data is affiliation data as it refers to membership or participation (Borgatti & Halgin, 2011). In affiliation data, individuals do not connect to each other but share common interests in connecting with certain groups. The groups do not directly connect with each other either; rather, they share the same group of individuals who want to connect with the same set of

groups. If an individual reports interest in connecting with a group or their new connection is from a group, their tie with that group was coded as one, otherwise zero. In the network data matrix, the rows were individual participants, and the columns were groups. We used two-mode graphs to visualize the network of interests (Network 1) and realized connections (Network 2).

Table 1. Network summary

Networks	Type	Surveys	Ties
1. Individual-group interest network	Two-mode	Pre-survey	Which group are you interested in connecting with
2. Individual-group realized network	Two-mode	Post-survey	Which group were your new connections from
3. Individual-individual realized network	Ego-network	Post-survey	Select individuals from a drop-of-list who you did not know before the workshop but shared information with at the workshop

Compared with the two-mode network data, the second type of network data from the post-survey question focused on peer-to-peer new information exchange ties (Network 3). The data captured individuals (egos) and the people they shared information with at the event (alters). These ties were a self-selected sample from all the occasions of new information exchange at the event. Whether a participant completed the network exercise on the post-survey and respondent recall bias affected who appeared in the emergent individual-to-individual realized network. Nevertheless, the emergent ties complement the two-mode individual-group realized network (Network 2) and help detail how the information network might be expanded after the event. To investigate the relationship between group affiliations, event speakers, and their presence in the emerging information network, two pairs of variables were used in chi-square analyses: (1) whether an individual finished the network exercise and their affiliations, and (2) whether an individual appeared in network 3 and whether they were a speaker at the event.

To explore how individuals were similar or different from the ones they shared information with, we used the E-I index, which captures both external (E) and internal (I) ties from the ego to their alters and to others within their affiliation group (Robins 2015). The letter "E" stands for the number of external ties, meaning ties with alters in different groups of the ego. In our study, E refers to how many new connections a person reported were from an affiliation group different from their own. The letter "I" stands for the number of internal ties, the number of connections from the same affiliation group of the ego. E-I index is the ratio between the number of external ties minus the number of internal ties divided by the total number of ties. The ratio ranges from -1 to 1, with values closer to -1 indicating all the ties of the ego were from the same group as the ego (perfect homophily) to 1 meaning all the ties of the ego were from groups different from the ego (perfect heterophily). Breakout group and affiliation were two categorical variables readily for E-I index calculations. We recorded the five-point ASP assessment questions into three categories, with zero referring to a negative view of ASP on criteria (combining scores one and two), one referring to a neutral view of ASP on criteria (score three), and three referring to a positive view of ASP (combining score four and five). We used Analysis of Variances ANOVA to compare individual node E-I index by their affiliation.

The analyses were conducted in SPSS and UCINET 6 (Borgatti et al. 2002).

RESULTS

A total of 76 individuals participated in the 2022 KBS LTAR stakeholder field day. The event participants represented seven stakeholder groups (Table 2). University-affiliated researchers and staff were the group most present in numbers at the event, accounting for 42% of all participants. Among these participants, 51 individuals (67%) responded to the pre-survey and 37 individuals (49%) to the post-survey. The affiliation profile of respondents to the two surveys

resembles the actual participant profile, except that agribusiness was underrepresented in the pre- and post-survey and farmer advisers were underrepresented in the post-survey.

Table 2. Event participant and survey respondent affiliation distribution.

Stakeholder Group	Total Participants	%	Pre-Survey Respondents	%	Post-Survey Respondents	%
Agribusiness	4	5%	0	0%	1	3%
Extension	5	7%	4	8%	3	8%
Farm Adviser	4	5%	3	6%	1	3%
Farmer	10	13%	8	16%	5	14%
Non-profit Orgs.	11	14%	7	14%	6	16%
Agencies	10	13%	8	16%	3	8%
University-Affiliated Researchers and Staff	32	42%	21	41%	18	49%

Note. 1. Percentages were rounded to the nearest integer, resulting in the sum of the percentages exceeding 100%. 2. Five farmers also reported affiliations with other groups, including non-profit organizations, agribusiness, farm advisers, and universities. A participant from a non-profit organization identified as university-affiliated researcher as well.

Stakeholder Interests Before the Event

The pre-survey asked respondents which group they would be interested in connecting with at the event, forming a two-mode network (Network 1; Figure 2).

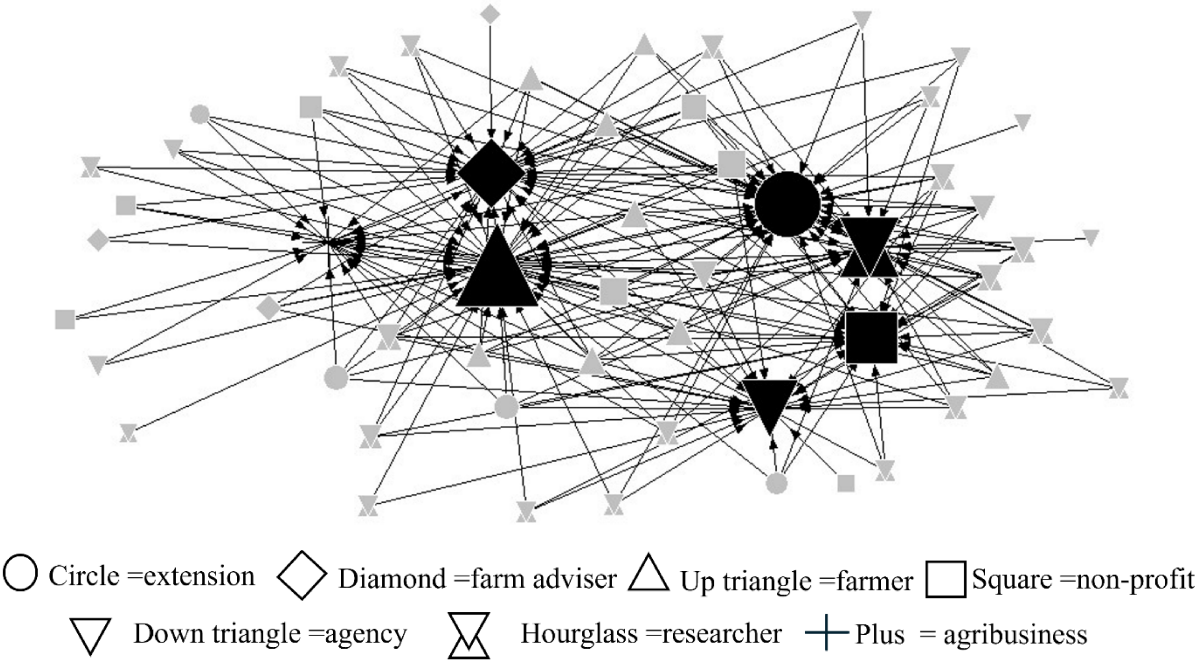


Figure 2. Two-mode interest network (Network 1). Grey nodes: respondents to the pre-survey. Black nodes: group. Lines: respondents indicated they were interested in networking with a group at the field workshop. The size of the nodes represents the degree. The shape represents affiliations.

The most interest in connections was directed toward farmers, with farm advisors and extension educators also receiving notable attention. This result points to a strong interest among participants in engaging with those who work directly in the agricultural field (Table 3). Most of the interests were cross-group, with many respondents selecting groups outside their own affiliation. Researchers had the least cross-group interest (67%) compared to other stakeholder groups.

Table 3. Groups attracting connection interests (in-degree of the group nodes in the two-mode network) indicated by the pre-survey respondents

	In-degree	Ties cross-group count	Ties cross-group %
Farmer	42	34	81
Farm advisor	32	30	94
Extension	31	31	100
Researcher	27	18	67
Agency	25	22	88
Agribusiness	20	20	100

Non-profit	22	19	86

From Interests to Connections At the Event

Participants' interests in building their professional networks across affiliation groups sparked the building of new connections. Of the 37 post-survey respondents, 36 indicated they met someone new at the event. The two-mode data reveals which affiliation group individuals' new connections were from (Network 2; Figure 3).

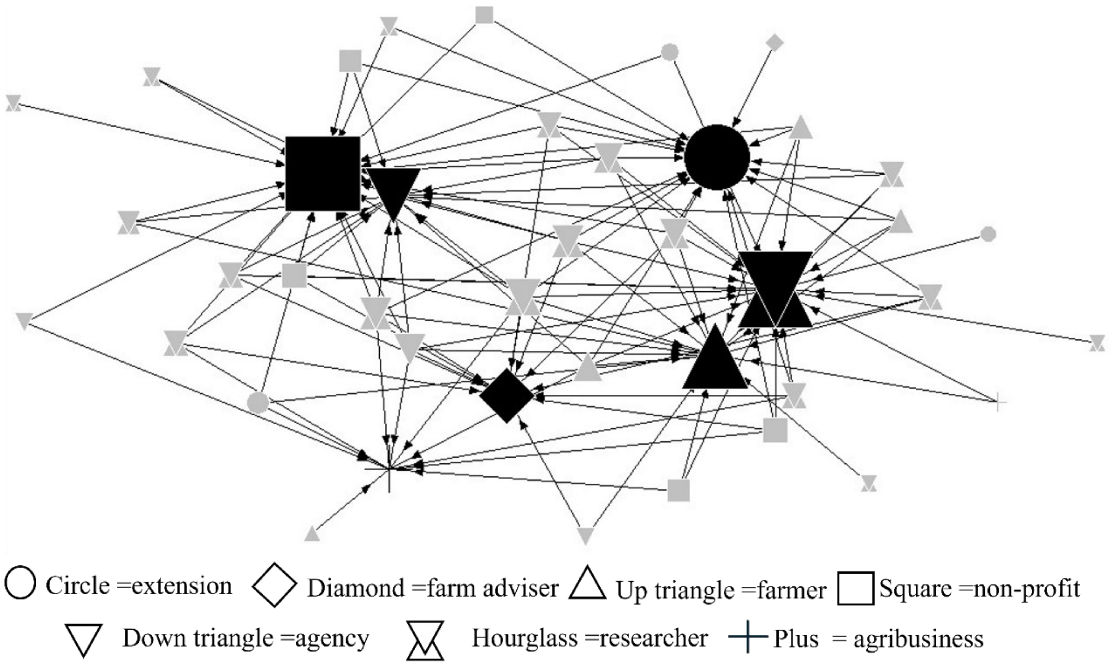


Figure 3. Two-mode realized network (Network 2). Grey nodes: respondents to the pre-survey. Black nodes: group. Lines: respondents indicated they were interested in networking with a group at the field workshop. The size of the nodes represents the degree. The shape represents affiliations.

Non-profit organizations and researchers received the most post-event connections, followed by farmers and extension (Table 4), although these groups, except farmers, did not attract the most connection interest from the pre-survey. Thirty-two university-affiliated researchers and staff attended the event, accounting for about 42% of the event participants. By comparison, only eleven participants were from a non-profit organization, yet an equal number

of new connections were made with people from non-profit organizations. Researchers exhibited more within-group interactions (50%) compared to other groups at the event, reflecting the high within-group connection interests observed in the pre-survey.

Table 4. Group receiving realized connections (in-degree of the group nodes in the two-mode network) indicated by the post-survey respondents.

	In-degree	Ties cross-group count	Ties cross-group %
Non-profit	20	17	85
Researcher	20	10	50
Farmer	17	14	82
Extension	17	17	100
Agency	14	13	93
Farm advisor	13	13	100
Agribusiness	11	11	100

Bridging Ties Formed at the Event

Among post-survey respondents, eighteen individuals finished the network exercise by selecting the name of at least one person they did not know before but shared information with at the event. Individuals selected one to six names, resulting in forty-three undirected ties of new information exchange. Three of these new information exchange ties were reciprocal, meaning both nodes that shared the information ties finished the network exercise and reported each other as information sharing. There was no significant relationship between affiliations and whether individuals finished the network exercise (Chi-square = 1.816, p-value = 0.874).

These ties were a sample of all the new information exchange ties brought about by the event. It is worth noting that the ties from the peer-to-peer network are fundamentally different from the two-mode data of individual new connections with groups, but they do both speak to the behavior of participating stakeholders. Moreover, whether a tie appeared in the sample depended on whether a participant finished the network exercise on the post-survey and whether they remembered the interaction. Hence, the results may not be broadly applicable. However, studying these emergent ties can help us understand the process of network expansion and the level of homophily among the new ties. In the last section of the results, we describe the

connectivity of information exchange ties and how these ties were organized by break-out groups, stakeholder presentations, affiliations, and views on ASP systems.

Figure 4 presents a network graph that includes all the new information exchange ties (Network 3). The ties were sparse but connected, rather than presenting a few isolated hubs of individuals and their alters. Those who finished the network exercise (black nodes) and those who did not (grey nodes) both served as connectors. Respondents from non-profit organizations and agencies tended to report more ties.

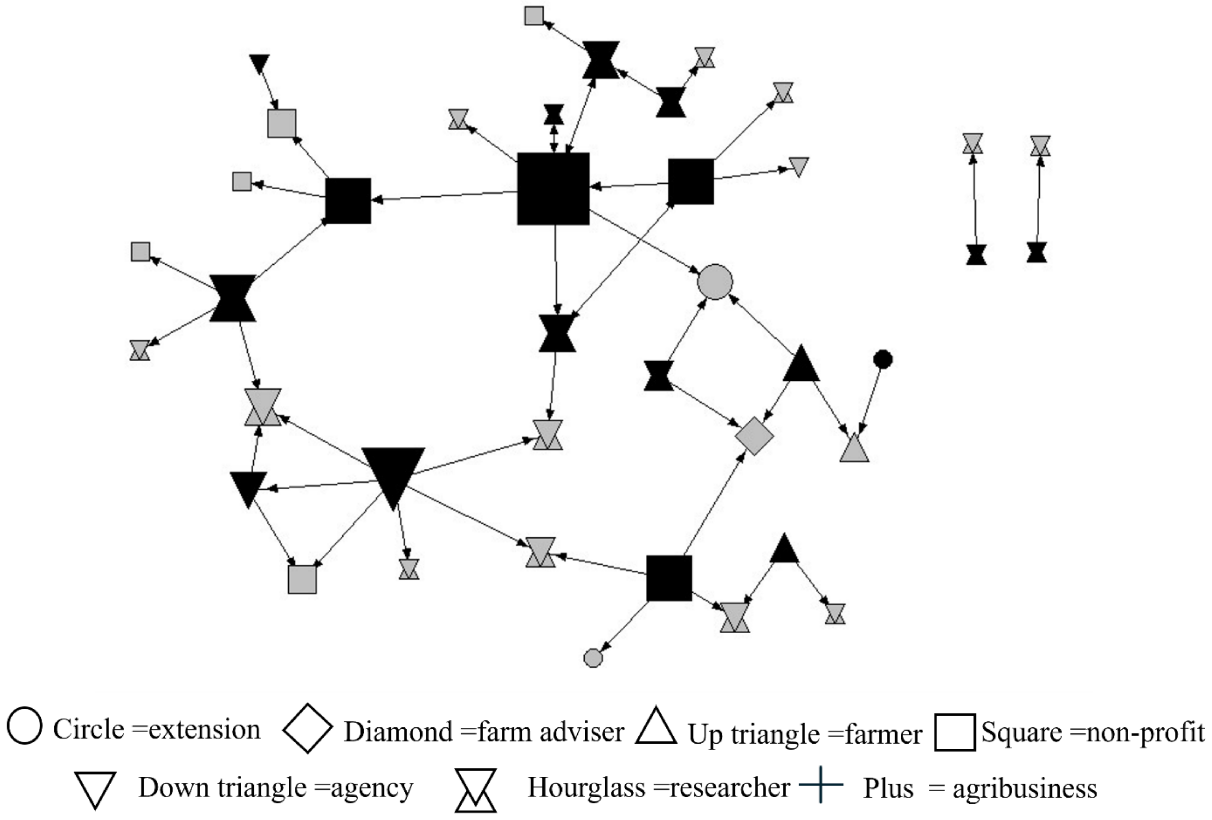


Figure 4. Individual-individual realized network (emergent information network, Network 3). Black nodes: individuals who finished the network exercise post-survey. Grey nodes: individuals who did not finish the network exercise but were mentioned by those who* did. *Lines:* individuals *indicated they* shared information with the other individual. *The size of the nodes represents the degree. The shape of the nodes represents affiliations.

Stakeholder speakers at the event seemed to be more likely to be present in the emergent network than non-speakers. Among the sixteen speakers, four individuals reported a total of sixteen ties, while six individuals were mentioned by other individuals. The percent of a speaker who participated in the post-survey and was present in the emergent information network (78%) was higher than the percent of non-speakers present in the network (65%), although the chi-square test was not significant (Chi-square = 2.112, p-value=.146).

The homophily analyses using E-I indices suggest that individuals might be more likely to form new connections outside of the breakout groups -- the structured discussion time. Out of the eighteen individuals, three (17%) reported new connections entirely from the same affiliation (E-I index = -1), while nine respondents (50%) reported connections only outside their breakout groups (E-I index = 1) (Table 5). The results do not imply that the breakout group failed to support relationship building. Instead, the data indicate the activities designed for informal interactions such as coffee breaks, meals, and wagon rides were effective in creating new information exchange ties.

The E-I indices, which use affiliation as the comparison attribute, suggest that most of the new information exchange ties occurred between individuals with different affiliations. Out of the eighteen respondents, four individuals (22%) reported new connections entirely from the same affiliation (E-I index = -1), while eight individuals (44%) reported new connections entirely from different affiliations (E-I index=1). The remaining respondents reported ties with at least one individual from a different affiliation group. Using ANOVA, affiliation groups did not differ in their E-I indices (F-statistic = 0.934, p-value = 0.474).

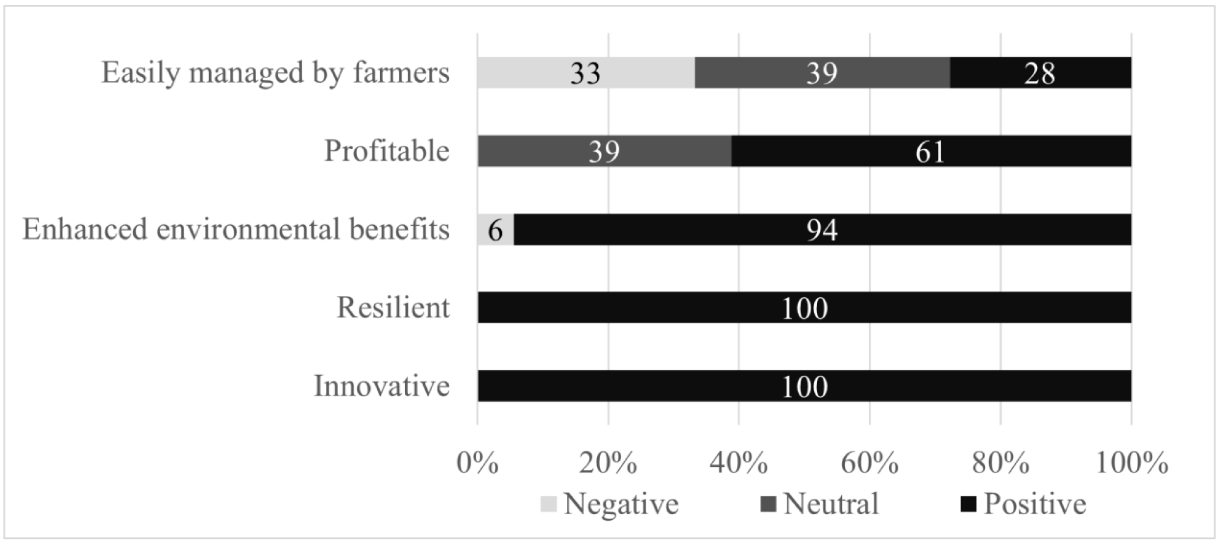
382 Table 5. Distribution of E-I indices by comparison attributes.

Comparison attribute	% E-I index = -1	% E-I index (-1, 0)	% E-I index =0	% E-I index (0, 1)	% E-I index = 1
Breakout groups	17	0	17	17	50
Affiliation	22	0	11	22	44
ASP-not resilient- resilient	100	0	0	0	0
ASP-ordinary-innovative	100	0	0	0	0
ASP-no additional environmental benefit-environmental benefit	57	7	14	0	21
ASP-unprofitable-profitable	36	14	7	0	43
ASP – not easily managed by farmers – easily managed by farmers	21	0	7	7	64

383 Note. Percentages were rounded to the nearest integer, resulting in the sum of the percentages
384 exceeding or below100%.

385

386 All the eighteen respondents who reported an information exchange tie rated ASP as
387 resilient and innovative (Figure 5), resulting in 100% E-I indices by these two criteria equaling to
388 -1 (Table 5). The majority of the respondents rated ASP as profitable (61%) and being able to
389 enhance environmental benefits (94%) (Figure 5); however, they tended to share information
390 with those who agreed with them on environmental benefits, indicated by 57% of respondents
391 with E-I index=-1, but disagreed with them on profitability, indicated by only 36% of
392 respondents with E-I index=-1 (Table 5). There was more variability in whether individuals
393 viewed the proposed ASP system as easily managed by farmers (64% EI-index=1).



394

395 ***Figure 5. Percent of individuals assessing of proposed ASP system by criteria.***

396 **DISCUSSION**

397 This study builds on the premise, adapted from Teodoro et al. (2021), that social
398 interactions at stakeholder engagement events, under certain conditions, can form social ties,
399 including information exchange ties. These ties, in turn, facilitate changes in perceptions and
400 actions at both the individual and network levels. We observed this process through a stakeholder
401 engagement event for the KBS LTAR project, designed to receive feedback on its research plans
402 and build and strengthen relationships with existing and new partners. Using two types of
403 network data—two-mode data connecting individuals with stakeholder groups and individual-to-
404 individual data—we observed three networks: a pre-event network showing how individuals
405 expressed interest in connecting with various stakeholder groups, a post-event network showing
406 which groups individuals formed new connections with, and a post-event network showing a
407 sample of the emergent information exchange ties.

408 The processes of social learning, social networks, and stakeholder participation are
409 interconnected. Changes in social network structures, network growth, integration, and

410 transformation are important conditions and indicators for social learning. Our results align with
411 those of Hoffman et al. (2015), Luján Soto et al. (2021), and Teodoro et al. (2021), supporting
412 the close connection between social networks and social learning. Through the description of
413 three networks, we detailed how participants, driven by an interest in connecting with others,
414 utilized interaction opportunities at stakeholder engagement events and formed new information
415 exchange ties with individuals from different affiliations and those with different views. A self-
416 reported sample of new information exchange ties (network 3) revealed connections not only
417 between individuals with different affiliations but also between individuals who have different
418 perspectives on ASP, creating opportunities for social learning.

419 Our findings highlight a key benefit of stakeholder engagement events: bringing multiple
420 stakeholders together and offering opportunities for sustained interaction and discussion. This
421 does not diminish the importance of engagement with single stakeholder groups, such as
422 engagement only with producers, as individuals within the same affiliation may hold different
423 views and beliefs (Armitage 2005; Bodin and Prell 2011). Interactions among people with the
424 same affiliation but different perceptions are an important and effective component of the social
425 learning process. However, for problems that require actions from multiple stakeholder groups,
426 academic institutions may serve as conveners and initiators of multi-stakeholder initiatives,
427 working to counter the natural tendency of homophily and promote connections between
428 different groups (Dentoni and Bitzer 2015). Academic institutions can benefit society and
429 stakeholders by using their resources to promote collaborations and networks (Holifield and
430 Williams 2019; Pagliarino et al. 2020).

431 Challenges arise in individual researchers' capacity and interests in connecting with
432 stakeholders. In our study, researchers showed a stronger interest in connecting with other

433 researchers and tended to have more within-group connections. The event had a significant
434 presence of university-affiliated researchers and staff, including graduate students whose
435 network capacity and motivations might differ from faculty members. Other studies have
436 identified challenges for researchers in engaging with stakeholders, such as a lack of training and
437 confidence, a lack of professional recognition for engagement efforts, and the tendency to
438 outsource engagement entirely to practitioners and social scientists (Jensen et al. 2008; Canfield
439 et al. 2022). With the growing recognition of stakeholder engagement and knowledge co-
440 production by funding agencies and institutions, more researchers are seeking to increase their
441 engagement capacity by attending training, collaborating with social scientists and boundary
442 organizations, and dedicating resources to hiring stakeholder engagement specialists. The
443 transformation of researchers themselves is also an outcome of social learning.

444 The agency of stakeholders in making connections is highlighted by our analysis of
445 participants' connection interests and actual connection activities. Studies have found that
446 stakeholder motivations, expectations, and involvement are critical to the success of stakeholder
447 engagement (Blackstock et al. 2012; Sterling et al. 2017; Canfield et al. 2022). Our results
448 revealed a high level of openness from stakeholders to connect with other groups. Although not
449 tested directly, openness may be a key condition for the emergence of ties among people with
450 different affiliations, along with interaction opportunities, facilitation, and participant
451 composition. The intricate relationship between stakeholder agency, design intentions, and
452 facilitation is demonstrated by the finding that realized individual-group connections did not
453 entirely match the individual-group interests. For example, there were more university-affiliated
454 researchers and staff at the event, and they were more likely to form new connections.

Meanwhile, non-profit affiliates and extension participants, although present in smaller numbers, actively reached out to other groups, serving as bridges and initiators in social learning.

This study functions as an interim evaluation of the ongoing stakeholder engagement effort. Instead of conducting a summative evaluation at the end of the project, like Van Der Wal et al. (2014), Tran et al. (2018), Luján Soto et al. (2021), we presented a formative evaluation at the early stage of a long-term project. Blackstock et al. (2007) listed four purposes for evaluation, which would take different weights in summative and formative evaluation: proving (illustrating efficiency or value), controlling (monitoring quality control), improving (reaching objectives), and learning (transforming the individual participant). The goal of our evaluation was to improve the stakeholder engagement effort at the KBS LTAR project and learn about relationship building and knowledge co-production in the process. For example, the results revealed nuances in stakeholder perception about aspirational agriculture practices. Individuals showed greater agreement with some criteria for assessing the proposed ASP (resilience, innovation) but greater disagreement with other criteria (manageability, profitability). This result can inform the common experiment to provide data on the economic performance and time costs to the stakeholders. It also establishes a baseline for stakeholder perceptions and will inform future efforts in assessing the social learning outcomes of the project's stakeholder engagement efforts.

The evaluation also suggested that stakeholder engagement events can be designed to foster social learning by incorporating facilitated discussions and allowing for sustained interactions during unstructured social time. One of the event's goals was to build and strengthen relationships with both existing and new partners. This goal was communicated to participants verbally and in writing, as it was printed on the second page of the agenda handout each

individual received. The pre-survey, which asked individuals about their intentions to connect, might have served as a prompt, encouraging people to focus on making new connections. Including stakeholder presentations, in addition to researchers' talks, diversified the perspectives at the event and may have promoted connections with the speakers, as evidenced by the new connections formed with them. The connection between the breakout groups and new connections was unclear, possibly because the breakout groups were pre-determined by the event organizers to balance new and existing connections. This also indicates that there were ample opportunities for individuals to connect outside of the designated discussion times.

A few limitations of the study are worth noting. The study was not designed to assert direct cause-and-effect relationships between variables. There were no control groups in an experiment setting that varied in the networking process and stakeholder design. The study did not assess whether social learning occurred either, as it did not directly measure the emergence of shared understanding or changes in participants' views of other groups. We intend to add this to our future data collection efforts, however. We interpret the observed stakeholder event design and respondent networks as a process in which stakeholder engagement leads to new connections that result in social learning, but it should not be taken as causality claims. Networking or sustained interaction does not always lead to shared understanding or positive results, even with well-designed stakeholder engagement events (Reed et al. 2018; Jalonen et al. 2020). Using the foundation established by previous studies (e.g., Luján Soto et al., 2021; Teodoro, et al., 2021), our study highlighted the connection between the processes of social learning, social network, and participatory research. More studies are needed to test the relationships between variables that measure, articulate, and assess the process.

We recognize that the dataset is not extensive or complex. Although the design was to follow participants before and after the event, fewer individuals filled out the post-survey than the pre-survey, and even fewer individuals finished the network exercise on the post-survey. The limitations of collecting detailed network data using quantitative surveys and the impact of multiple contacts on response rates have been noted. As a result, the emergent information exchange network missed many new but weaker connections, limiting our ability to examine network-level characteristics. In addition, the post-survey was collected a month after the event through a self-administered online survey, suggesting challenges with recalling information and thus fully completing the connection detail. We checked that there was no statistical difference in the number of reported ties by affiliation groups.

We suggest a few future research directions that could advance the study of the participatory research process and its outcomes for social learning. Interviews with stakeholders that include a network exercise are more likely to collect information on the whole network. Studying the emergent network at various time intervals will also be important as it will demonstrate the evolvement of the network and identify which ties will be deepened or fade over time. Lastly, future research could document how ideas for new practices exchanged in a network can be planted, confirmed, germinated into actions, and supported through the trial period, and how individuals on the receiving end of ideas in the network can switch their roles and become idea disseminators themselves at some future date.

CONCLUSION

Agroecosystems face many challenges such as climate change, soil degradation, biodiversity losses, and nutrient pollution that require coordinated and voluntary actions from a wide range of stakeholders including agricultural producers, agribusinesses, researchers and

educators, policymakers, and environmental and agricultural organizations. Stakeholder engagement efforts initiated by research institutions can provide space, opportunities, and motivations for network expansion between different stakeholder groups to allow social learning to occur. The ultimate goal is to build a mutual understanding of an issue and a willingness to take action despite individual or group differences. The social learning approach supported by a framework including social network analysis can help researchers design their stakeholder engagement activities based on stakeholder interests in order to maximize outcomes. Successful solutions to many natural resource problems will rely on the ability of or how well different groups learn and act together. At the individual level, new ties, especially those with individuals who are different, expose people to new information or challenge how they view the world, providing opportunities for learning through interactions.

Our study demonstrates the importance of understanding stakeholders' interests in stakeholder engagement events. Depending on stakeholders' previous experience with research projects and other stakeholders, and on whether there are existing relationships among stakeholder groups, people's interests in networking with others could be vastly different. Researchers and stakeholder engagement practitioners should not make assumptions that activities aimed at networking will always receive positive feedback. The potential burden on farmers is also worth considering, since various groups showed interest in connecting with farmers, prompting the key question of what benefits farmers can receive from the new connections. Stakeholder engagement efforts should have clear outcome goals along with an assessment plan. If possible, stakeholder engagement should be considered a long-term effort as the building of trust and coordination capacity takes time. Having a strategic plan and dedicated

resources and personnel for stakeholder engagement is essential for stakeholder engagement to achieve long-term social learning outcomes.

APPENDIX

Survey question gauging stakeholders on the proposed ASP system

Thank you for your insights on the KBS LTAR experiment plans, including measurements and metrics. The long-term experiment contrasts an "aspirational" system of the future against today's "business as usual" cash grain system. The aspirational system includes a 5-year rotation and management practices intended to optimize production efficiency along with environmental and rural prosperity outcomes such as soil health, greenhouse gas mitigation, biodiversity, water quality, and profitability.

1. Based on the information provided, how would you evaluate the proposed Aspirational System (5-year rotation and management practices over time) according to the following criteria?

	1	2	3-Neutral	4	5	
Ordinary	○	○	○	○	○	Innovative
Unprofitable	○	○	○	○	○	Profitable
Not resilient	○	○	○	○	○	Resilient
No additional environmental benefits	○	○	○	○	○	Enhanced environmental benefits
Not easily managed by farmers	○	○	○	○	○	Easily managed by farmers

REFERENCES

Amblard, Laurence. 2021. Collective action as a tool for agri-environmental policy implementation. The case of diffuse pollution control in European rural areas. *Journal of Environmental Management* 280. Academic Press. https://doi.org/10.1016/j.jenvman.2020.111845.

555 Armitage, Derek. 2005. Adaptive capacity and community-based natural resource management.
556 *Environmental Management*. https://doi.org/10.1007/s00267-004-0076-z.

557 Barnes, Michele L., Lorien Jasny, Andrew Bauman, Jon Ben, Ramiro Berardo, Örjan Bodin,
558 Joshua Cinner, et al. 2022. 'Bunkering down': How one community is tightening social-
559 ecological network structures in the face of global change. *People and Nature* 4. John Wiley
560 and Sons Inc: 1032–1048. https://doi.org/10.1002/pan3.10364.

561 Blackstock, K. L., G. J. Kelly, and B. L. Horsey. 2007. Developing and applying a framework to
562 evaluate participatory research for sustainability. *Ecological Economics* 60: 726–742.
563 https://doi.org/10.1016/j.ecolecon.2006.05.014.

564 Blackstock, K. L., K. A. Waylen, J. Dunglinson, and K. M. Marshall. 2012. Linking process to
565 outcomes - Internal and external criteria for a stakeholder involvement in River Basin
566 Management Planning. *Ecological Economics* 77: 113–122.
567 https://doi.org/10.1016/j.ecolecon.2012.02.015.

568 Bodin, O., and C. Prell. 2011. *Social networks and natural resource management: uncovering*
569 *the social fabric of environmental governance*. Cambridge, UK: Cambridge University
570 Press.

571 Borgatti, S. P, and D.S. Halgin. 2011. Analyzing affiliation networks. In *The SAGE Handbook of*
572 *Social Network Analysis*.

573 Borgatti, S.B., M.G. Everrett, and J.C. Johnson. 2013. *Analyzing Social Networks*. Sage
574 Publication UK.

Borgatti, S.P., M.G. Everett, and L.C. Freeman. 2002. Ucinet for Windows: Software for Social Network Analysis. Harvard, MA: Analytic Technologies.

Brymer, B. Amanda L., J. D. Wulfhorst, and Mark W. Brunson. 2018. Analyzing stakeholders' workshop dialogue for evidence of social learning. *Ecology and Society* 23. Resilience Alliance. https://doi.org/10.5751/ES-09959-230142.

Buchecker, Matthias, Marius Fankhauser, and Raphael Gaus. 2023. Finding shared solutions in landscape or natural resource management through social learning: A quasi-experimental evaluation in an Alpine region. *Landscape Ecology* 38. Springer Science and Business Media B.V.: 4117–4137. https://doi.org/10.1007/s10980-021-01274-y.

Canfield, Katherine N., Kate Mulvaney, and Casey D. Chatelain. 2022. Using researcher and stakeholder perspectives to develop promising practices to improve stakeholder engagement in the solutions-driven research process. *Socio-Ecological Practice Research* 4. Springer: 189–203. https://doi.org/10.1007/s42532-022-00119-5.

Charnley, Susan, Erin C. Kelly, and A. Paige Fischer. 2020. Fostering collective action to reduce wildfire risk across property boundaries in the American West. *Environmental Research Letters* 15. Institute of Physics Publishing. https://doi.org/10.1088/1748-9326/ab639a.

Cundill, G., and R. Rodela. 2012. A review of assertions about the processes and outcomes of social learning in natural resource management. *Journal of Environmental Management*. Academic Press. https://doi.org/10.1016/j.jenvman.2012.08.021.

Dentoni, Domenico, and Verena Bitzer. 2015. The role(s) of universities in dealing with global wicked problems through multi-stakeholder initiatives. In *Journal of Cleaner Production*, 106:68–78. Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2014.09.050.

Eaton, Weston M., Kathryn J. Brasier, Mark E. Burbach, Walt Whitmer, Elyzabeth W. Engle, Morey Burnham, Barbara Quimby, et al. 2021. A Conceptual framework for social, behavioral, and environmental change through stakeholder engagement in water resource management. *Society and Natural Resources* 34. Routledge: 1111–1132. https://doi.org/10.1080/08941920.2021.1936717.

Fernández-Giménez, María E., David J. Augustine, Lauren M. Porensky, Hailey Wilmer, Justin D. Derner, David D. Briske, and Michelle O. Stewart. 2019. Complexity fosters learning in collaborative adaptive management. *Ecology and Society* 24. Resilience Alliance. https://doi.org/10.5751/ES-10963-240229.

Fischer, A. Paige, and Lorien Jasny. 2017. Capacity to adapt to environmental change: Evidence from a network of organizations concerned with increasing wildfire risk. *Ecology and Society* 22. Resilience Alliance. https://doi.org/10.5751/ES-08867-220123.

Hoffman, Matthew, Mark Lubell, and Vicken Hillis. 2015. Network-smart extension could catalyze social learning. *California Agriculture* 69. University of California, Oakland: 113–122. https://doi.org/10.3733/ca.E.v069n02p113.

Holifield, Ryan, and Kathleen C. Williams. 2019. Recruiting, integrating, and sustaining stakeholder participation in environmental management: A case study from the Great Lakes Areas of Concern. *Journal of Environmental Management* 230. Academic Press: 422–433. https://doi.org/10.1016/j.jenvman.2018.09.081.

Hutchins, Karen, Laura A. Lindenfeld, Kathleen P. Bell, Jessica Leahy, and Linda Silka. 2013. Strengthening knowledge co-production capacity: Examining interest in community-

university partnerships. *Sustainability (Switzerland)* 5. MDPI: 3744–3770. https://doi.org/10.3390/su5093744.

Jackson-Smith, D., S. Ewing, C. Jones, A. Sigler, and A. Armstrong. 2018. The road less traveled: Assessing the impacts of farmer and stakeholder participation in groundwater nitrate pollution research. *Journal of Soil and Water Conservation* 73. Soil Conservation Society of America: 610–622. https://doi.org/10.2489/jswc.73.6.610.

Jalonen, Harri, Alisa Puustinene, and Harri Raisio. 2020. The hidden side of co-creation in a complex multi-stakeholder environment: When self-organization fails and emergence overtakes. In *Society as an interaction space: a systemic approach*, ed. Hanna Lehtimäki, Petri Uusikylä, and Anssi Smedlund, 3–22.

Jensen, Pablo, Jean Baptiste Rouquier, Pablo Kreimer, and Yves Croissant. 2008. Scientists who engage with society perform better academically. *Science and Public Policy* 35. Beech Tree Publishing: 527–541. https://doi.org/10.3152/030234208X329130.

Kadushin, C. 2012. *Understanding Social Networks: Theories, Concepts, and Findings*. New York: Oxford University Press.

Luján Soto, Raquel, Mamen Cuéllar Padilla, María Rivera Méndez, Teresa Pinto-Correia, Carolina Boix-Fayos, and Joris de Vente. 2021. Participatory monitoring and evaluation to enable social learning, adoption, and out-scaling of regenerative agriculture. *Ecology and Society* 26. Resilience Alliance. https://doi.org/10.5751/ES-12796-260429.

Mcpherson, Miller, Lynn Smith-Lovin, and James M Cook. 2001. *Birds of a Feather: Homophily in Social Networks*.

639 Moody, James, and Pamela Paxton. 2009. Building bridges: Linking social capital and social
640 networks to improve theory and research. *American Behavioral Scientist* 52: 1491–1506.
641 https://doi.org/10.1177/0002764209331523.

642 Mostert, Erik, Claudia Pahl-Wostl, Yvonne Rees, Brad Searle, David Tàbara, and Joanne Tippett.
643 2007. Social Learning in European River-Basin Management: Barriers and Fostering
644 Mechanisms from 10 River Basins. *Ecology and Society* 12. and Society: xx–xx.

645 Muro, M., and P. Jeffrey. 2008. A critical review of the theory and application of social learning
646 in participatory natural resource management processes. *Journal of Environmental Planning*
647 *and Management*. https://doi.org/10.1080/09640560801977190.

648 Neef, Andreas, and Dieter Neubert. 2011. Stakeholder participation in agricultural research
649 projects: A conceptual framework for reflection and decision-making. *Agriculture and*
650 *Human Values* 28. Kluwer Academic Publishers: 179–194. https://doi.org/10.1007/s10460-
651 010-9272-z.

652 Nikkels, Melle J., Peat Leith, Saideepa Kumar, Neville Mendham, and Art Dewulf. 2021. The
653 social learning potential of participatory water valuation workshops: A case study in
654 Tasmania, Australia. *Environmental Policy and Governance* 31. John Wiley and Sons Ltd:
655 474–491. https://doi.org/10.1002/eet.1939.

656 O'Connor, Ruth A., Jeanne L. Nel, Dirk J. Roux, Lilly Lim-Camacho, Lorrae van Kerkhoff, and
657 Joan Leach. 2019. Principles for evaluating knowledge co-production in natural resource
658 management: Incorporating decision-maker values. *Journal of Environmental Management*
659 249. Academic Press. https://doi.org/10.1016/j.jenvman.2019.109392.

Pagliarino, Elena, Francesca Orlando, Valentina Vaglia, Secondo Rolfo, and Stefano Bocchi. 2020. Participatory research for sustainable agriculture: the case of the Italian agroecological rice network. *European Journal of Futures Research* 8. Springer. https://doi.org/10.1186/s40309-020-00166-9.

Reed, Mark S, Anna C Evely, Georgina Cundill, Ioan Fazey, Jayne Glass, Adele Laing, Jens Newig, et al. 2010. What is social learning? *Ecology and Society* 15. and Society: xx–xx.

Reed, Mark S., Steven Vella, Edward Challies, Joris de Vente, Lynne Frewer, Daniela Hohenwallner-Ries, Tobias Huber, et al. 2018. A theory of participation: what makes stakeholder and public engagement in environmental management work? *Restoration Ecology*. Blackwell Publishing Inc. https://doi.org/10.1111/rec.12541.

Reimer, Adam P., Riva C.H. Denny, and Diana Stuart. 2018. The Impact of Federal and State Conservation Programs on Farmer Nitrogen Management. *Environmental Management* 62. Springer New York LLC: 694–708. https://doi.org/10.1007/s00267-018-1083-9.

Robins, G. 2015. *Doing Social Network Research: Network-based Research Design for Social Scientists*. SAGE Publications Ltd.

Sachet, Erwan, Ole Mertz, Jean François Le Coq, Gisella S. Cruz-Garcia, Wendy Francesconi, Muriel Bonin, and Marcela Quintero. 2021. Agroecological transitions: A systematic review of research approaches and prospects for participatory action methods. *Frontiers in Sustainable Food Systems*. Frontiers Media S.A. https://doi.org/10.3389/fsufs.2021.709401.

Skaalsveen, Kamilla, Julie Ingram, and Julie Urquhart. 2020. The role of farmers' social networks in the implementation of no-till farming practices. *Agricultural Systems* 181. Elsevier Ltd. https://doi.org/10.1016/j.agsy.2020.102824.

Sterling, Eleanor J., Erin Betley, Amanda Sigouin, Andres Gomez, Anne Toomey, Georgina Cullman, Cynthia Malone, et al. 2017. Assessing the evidence for stakeholder engagement in biodiversity conservation. *Biological Conservation*. Elsevier Ltd. https://doi.org/10.1016/j.biocon.2017.02.008.

Teodoro, Jose Daniel, Christina Prell, and Laixiang Sun. 2021. Quantifying stakeholder learning in climate change adaptation across multiple relational and participatory networks. *Journal of Environmental Management* 278. Academic Press. https://doi.org/10.1016/j.jenvman.2020.111508.

Tran, Thong Anh, Helen James, and Jamie Pittock. 2018. Social learning through rural communities of practice: Empirical evidence from farming households in the Vietnamese Mekong Delta. *Learning, Culture and Social Interaction* 16. Elsevier Ltd: 31–44. https://doi.org/10.1016/j.lcsi.2017.11.002.

US Department of Agriculture. 2024. *Strategic Plan Long-Term Agroecosystem Research Network*.

de Vente, Joris, Mark S. Reed, Lindsay C. Stringer, Sandra Valente, and Jens Newig. 2016. How does the context and design of participatory decision making processes affect their outcomes? Evidence from sustainable land management in global drylands. *Ecology and Society* 21. Resilience Alliance. https://doi.org/10.5751/ES-08053-210224.

Wade, Belinda, Bishal Bharadwaj, Amrita Kambo, Mikayla Jensen, Katherine Witt, Franzisca Weder, Anna Phelan, and Peta Ashworth. 2024. Stakeholder engagement: the role of facilitators and gender in ‘opening up’ conversations and enabling participation.

Australasian Journal of Environmental Management 31. Taylor and Francis Ltd.: 7–39. https://doi.org/10.1080/14486563.2023.2298195.

Van Der Wal, Merel, Joop De Kraker, Astrid Offermans, Carolien Kroeze, Paul A. Kirschner, and Martin van Ittersum. 2014. Measuring social learning in participatory approaches to natural resource Management. *Environmental Policy and Governance* 24: 1–15. https://doi.org/10.1002/eet.1627.

Wilmer, Hailey, Terri Schulz, María E. Fernández-Giménez, Justin D. Derner, Lauren M. Porensky, David J. Augustine, John Ritten, Angela Dwyer, and Rachel Meade. 2022. Social learning lessons from Collaborative Adaptive Rangeland Management. *Rangelands* 44. Society for Range Management: 316–326. https://doi.org/10.1016/j.rala.2021.02.002.