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Assessing the impacts of stakeholder involvement in long-term agricultural experiments via a case study in the upper US Midwest

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Abstract

Agricultural researchers are increasingly encouraged to engage with stakeholders to improve the usefulness of their projects, but iterative research on the design and assessment of stakeholder engagement is scarce. The USDA Long-Term Agroecosystem Research (LTAR) Network recognizes the importance of effective engagement in increasing the utility of information and technologies for future agriculture. Diverse stakeholders and researchers at the Kellogg Biological Station (KBS) LTAR site co-designed the KBS LTAR Aspirational Cropping System Experiment, a process that provides a testing ground and interdisciplinary collaborations to develop theory-driven assessment protocols for continuous stakeholder engagement. Informed by prior work, we designed an assessment protocol that aims to measure participant preferences, experiences, and perceived benefits at various stages of this long-term project. Two online surveys were conducted in 2021 and 2022 among participants of LTAR engagement events at KBS, using a pre-post design, resulting in 125 total responses. Survey respondents had positive perceptions of the collaboratively designed research experiment. They had a strong expectation that the research would generate conservation and environmental advances while also informing policy and programs. Respondents also indicated a desire to network with other stakeholders. The research team noted the significant role of a long-term stakeholder engagement specialist in inviting participants from diverse backgrounds and creating an open and engaging experience. Overall, results highlight an interdisciplinary path of intentional and iterative engagement and evaluation to build a program that is adaptive and responsive to stakeholder needs.

Abbreviations: ACSE, Aspirational Cropping System Experiment; ASP, aspirational agriculture practice or cropping or ranching systems; BAU, prevailing business-as-usual practices; KBS, Kellogg Biological Station; LTAR, Long-Term Agroecosystem Research.

Plain Language Summary

Involving stakeholders in research should benefit both the researchers and the stakeholders. This paper explains how the Kellogg Biological Station (KBS) LTAR site worked with agricultural professionals to design an experiment that compared current farming practices with what farming could look like in the future. Surveys were used to find out what participants hoped to gain from being involved and if their expectations were met. Their opinions about the future farming approach were also studied. The results showed that participants were looking for new ideas, policy support, and opportunities to connect with others. They showed more interest and a desire to stay involved after participation, and they had positive views on the future farming ideas. Using social science methods to assess how stakeholders are engaged helps improve project design and ensures that both participants and researchers benefit.

1 | INTRODUCTION

Transformative agricultural research can help create actionable innovation to balance profitability, community prosperity, and environmental well-being. The Long-Term Agroecosystem Research (LTAR) Network of the US Department of Agriculture (USDA) seeks to develop national strategies for sustainable agriculture through long-term Common Experiments (Liebig et al., 2024; Robertson et al., 2024), which contrast prevailing or business-as-usual agriculture practices (BAU) against aspirational or alternative cropping or ranching (ASP) systems at 18 sites across the nation. The diverse and unpredictable nature of LTAR sites' contexts and environments both enriches and complicates creating a vision for an alternative system.

Various stakeholder groups view the ideal future for agriculture—and the route to achieve it—differently, since they bring their unique values, perceptions, and ways of knowing to the table. The saliency, legitimacy, credibility, and usability of proposed innovations hinge on critical stakeholder input from diverse groups (Falconi & Palmer, 2017; Lilja & Dixon, 2008). A salient innovation broadly reflects the interests of those involved (Bracken et al., 2015). A usable innovation considers constraints, variability, and uncertainty and can be easily used in many contexts (Lemos & Morehouse, 2005). Communication between scientists and decision-makers is also critical for the credibility and legitimacy of information (Cash et al., 2003; Falconi & Palmer, 2017). Engaging stakeholders and developing meaningful connections with a wide range of stakeholders, fostering trust, collaboration, and capacity, will enhance the likelihood of stakeholder support for innovations like the ASP systems and their long-term implementations (Garlick & Fallon, 2023; Lemos & Morehouse, 2005).

Here we report on an effort to gauge stakeholder views on an ASP system formed through a series of stakeholder engagement events hosted at the Kellogg Biological Station (KBS) LTAR site (Robertson et al., 2024) and evaluate the effectiveness of engagement efforts. We consider stakeholder engagement a broad concept describing processes in which scientists and science professionals intentionally interact and communicate about science (Garlick & Fallon, 2023). Beyond the traditional linear model of engagement, researchers appreciate a variety of engagement modes, distinguished by differing levels of participation, engagement goals, forms of agency (who initiates and leads the process can vary), and researcher and stakeholder characteristics (Garlick & Fallon, 2023; Neef & Neubert, 2011; Reed et al., 2018). As Garlick and Fallon (2023) advocate, research institutions should build a portfolio of engagement that evolves to integrate different engagement modes reflecting unique contexts (e.g., Jackson-Smith et al., 2018).

Assessing engagement's effectiveness is important for a research project's strategic evolution or an institution's engagement portfolio. We define effectiveness as achieving desired results. The evaluation process should involve specifying goals (desired outcomes) and measuring how these goals are accomplished (Varner, 2014). Social science literature presents a wide range of engagement outcomes, such as information, learning, and trust, for researchers to consider. For example, Wall et al. (2017) summarized 45 indicators for effectively co-producing usable climate science, covering inputs, processes, outputs, outcomes, impacts, and external factors of co-produced climate science. Wiek et al. (2014) categorized the effects of participatory research into four groups, including usable products, enhanced capacity, network effects, and structural changes and actions. Evaluation methods vary too, including qualitative approaches (Carton et al., 2022), quantitative approaches (Guo et al., 2024), and mixed approaches (Jackson-Smith et al., 2018). Blackstock et al. (2007) highlighted the benefits of formative evaluation, performed during the project to improve engagement efforts

and promote learning. Carr et al. (2012) argue that intermediate outcomes evaluation should be assessed as they directly reflect the participation process and mechanisms. Building on a diverse literature of stakeholder engagement, we emphasize two principles, reciprocity and iteration, as key in guiding the design and evaluation of engagement efforts.

First, in the case of reciprocity, assessments should incorporate participant expectations as key engagement outcomes, highlighting the complementary benefits that stakeholder engagement offers to participants, researchers, and society. Scientists usually have an idea of the input needed from stakeholders, such as seeking feedback on their research proposals and context or details about nuance that might have been overlooked. Social scientists and stakeholder practitioners alike have warned of the danger of tokenized engagement without reciprocity (Arnstein, 2019; Garlick & Fallon, 2023; Neef & Neubert, 2011). Various reasons can motivate stakeholders, including curiosity, care for the problem, or interest in working on an interdisciplinary team (Bracken et al., 2015; Ferguson et al., 2017; Veisi et al., 2022). However, without experiencing clear benefits (i.e., outcomes of value), the interest and commitment to participate can wane over time, even leading to a sense of the process' being extractive or unproductive (Holifield & Williams, 2019; O'Connor et al., 2019). Benefits to participants, and recognizing that benefits can vary among stakeholders and researchers, should drive the design of stakeholder engagement (Neef & Neubert, 2011). Understanding stakeholder interests and preferences at a project's early stage is important, as scientists and stakeholders may rate the importance and likelihood of achieving outcomes differently (Veisi et al., 2022). Formative evaluation gauging helps align stakeholders' expectations and preferences and lays the groundwork for context-appropriate decisions and effective engagement efforts (Sterling et al., 2017).

Second, in the case of iteration, an assessment process, including goal-setting, design, implementation, and evaluation, should be iterative (Garlick & Fallon, 2023). Rarely can scientists foresee all relevant outcomes and intended impacts in advance, as well as all design details and evaluation methods. As the project proceeds, new outcomes can emerge. Meanwhile, outcomes like behavior change, trust building, coalition forming, and system-level transformation take a long time to achieve (Blackstock et al., 2007; Jackson-Smith et al., 2018; Reed et al., 2010), while short-term outcomes are process indicators, helping to calibrate stakeholder efforts, spot unintended impacts, and create windows for new impacts (Blackstock et al., 2012; Sterling et al., 2017; Wall et al., 2017). Alongside detailed reviews at the end of projects, scientists can integrate formative assessments that can be repeated with lower resource intensity and can encourage learning for all involved (Blackstock et al., 2007). An iterative stakeholder engagement program built on reciprocity resembles adaptive management and transdisciplinary research, which involves researchers from various fields coming together to undertake steps such as goal setting, action, monitoring, reflecting, and adjusting (Williams et al., 2009).

Core Ideas

- The Kellogg Biological Station (KBS) LTAR site engages stakeholders in a long-term, reciprocal program.
- Stakeholders and researchers co-produced the KBS Aspirational Cropping System Experiment (ACSE).
- Two surveys demonstrate increased stakeholder interest, improved understanding, and stronger relationships.
- Diverse stakeholders expressed positive views about the KBS ACSE.
- Social science assessments guide the adaptive, iterative design of stakeholder engagement programs.

Built on these two principles, we outline the transdisciplinary efforts at the KBS LTAR site to assess stakeholder engagement strategies iteratively, informing the development of the innovative or aspirational system for the site's Common Experiment (Robertson et al., 2024). We sought to assess whether stakeholder expectations have been met through KBS' engagement efforts and how stakeholders view the proposed ASP system. Two surveys were designed and conducted to accompany stakeholder engagement events in 2021 and 2022. In the following, we explain how the KBS LTAR research team integrated stakeholder engagement into the ASP's system design and how complementary social science research informed the selection of performance indicators for the stakeholder engagement program. We then describe the assessment methods and results, followed by a reflection on the iterative assessment process and the role of social scientists and social science research principles.

1.1 | Overview of KBS LTAR ASP design

The KBS LTAR site represents the northeast part of the North Central Region, covering 76,000 km^2 across southern Michigan and northern Indiana (Robertson et al., 2024). KBS has been a Long-term Ecological Research (LTER) site since 1988 with a focus on the agricultural ecology of Midwest row crops. Over the years, KBS has built a tradition of working with stakeholders. Built on the trust and network initiated with KBS LTER efforts, KBS LTAR codesigned its BAU and ASP treatments with stakeholders for its instance of the

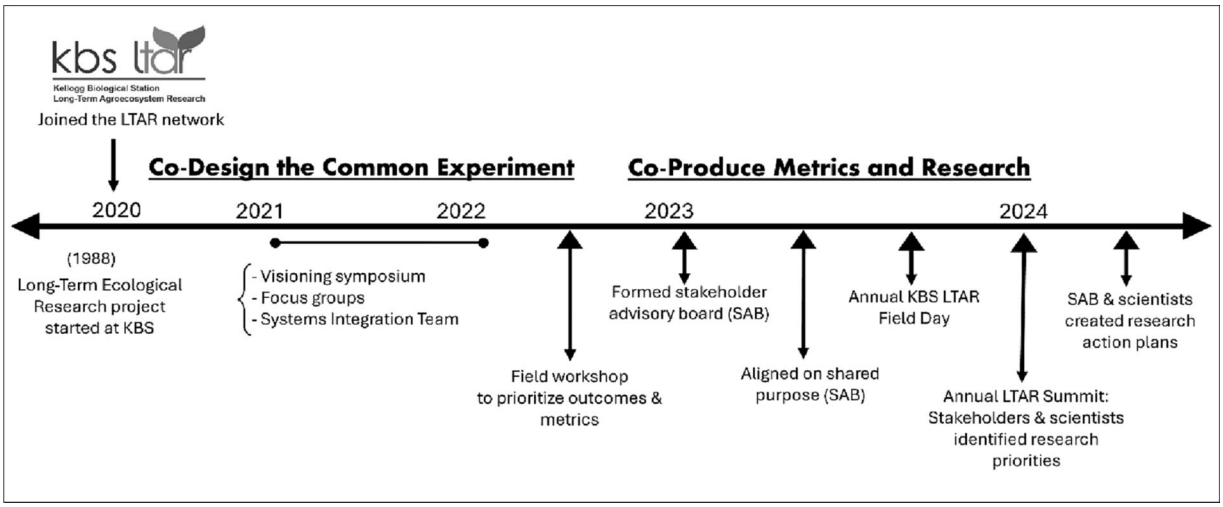

FIGURE 1 Timeline of stakeholder engagement periods and activities at Kellogg Biological Station (KBS) LTAR.

Network's Common Experiment, locally called the Aspirational Cropping System Experiment (ACSE). The BAU treatment of ACSE matches the region's prevailing cropping system and was identified using USDA statistics supplemented by farmer surveys (Guo, Marquart-Pyatt, Robertson, 2023) and informal stakeholder consultation (Robertson et al., 2024). The BAU treatment was specified as a corn–soybean rotation chisel plowed in the fall or spring followed by secondary tillage pre-plant, with no cover crops or manure. Inputs such as fertilizers and pesticides are applied consistently with prevailing timing and rates.

In a series of workshops initiated in 2021 prior to the start of the experiment and continued in 2022 and subsequent years, stakeholders and researchers collaboratively designed the ASP system (Figure 1). The stakeholders involved and the process are described below. The co-designed ASP treatment is a five-crop rotation of corn (*Zea mays*), soybean (*Glycine max*), winter wheat (*Triticum aestivum*), winter canola (*Brassicus napus*), and a perennial forage mix to be either grazed or harvested for off-site consumption (Robertson et al., 2024). The treatment also includes a suite of layered conservation practices that represent desired outcomes by stakeholders (described below), including continuous no-till, cover crops, integrated pest management, precision nutrient management, perennial prairie plantings in unprofitable or difficult-to-manage subfield areas, and manure addition.

The ASP treatment was designed with professionals who work in the agricultural or environmental domains. Individuals representing six primary groups have been engaged thus far, including (1) conventional and innovative producers; (2) agricultural professionals (crop advisers, university extension educators, and seed, fertilizer, and crop protection retailers); (3) conservation professionals from nonprofit organizations and the USDA Natural Resources Conservation Service; (4) social actors in the policy realm from farm organizations, commodity groups, and legislative staff and state agencies such as the Michigan Department of Natural Resources and Michigan Department of Agriculture and Rural Development; (5) commodity buyers such as milling companies; and (6) public-facing retailers like food processors (Robertson et al., 2024).

In this paper, we focus on two relevant KBS stakeholder engagement events that led to the ASP treatment's development. Event 1 in 2021 was a series of events, including a virtual visioning symposium that invited agricultural leaders to imagine the future of agriculture, followed by focus group discussions. A KBS stakeholder engagement specialist embedded in the local network hosted the series of online events. The event and follow-up focus groups revealed the desired outcomes for future farming systems, including profitability, soil health, greenhouse gas mitigation, and biodiversity conservation, along with key elements to deliver the prioritized outcomes, such as high crop diversity, high circularity, year-round plant cover, continuous no-till, precision technologies, prairie strips, and livestock for grazing forage or cover crops and for composted manure (Robertson et al., 2024). A system design team, comprised of farmers, crop advisers, university agronomists, and other scientists, used these prioritized outcomes and design elements to collectively design the ASP system throughout several workshops. Following both the initial visioning symposium and design team meetings, an online survey was circulated to gauge wider responses to the proposed ASP treatment, prioritized experiment outcomes, and the stakeholder events' impact.

Event 2 was a day-long field workshop at KBS in summer 2022. The event included in-field tours; presentations from researchers, policymakers, farmers, and NGOs; reflection and discussion sessions; and networking opportunities over coffee and lunch breaks. The goals of the day were threefold: building and strengthening relationships with existing

and new partners, hearing from partners on the current context of Midwestern farming and conservation, and receiving feedback and advice on the KBS LTAR experiment plans. The project leadership team, including the stakeholder engagement specialist, co-designed and hosted the event, ensuring participants were welcomed and engaged throughout the day. Compared with 2021, the data collection was more intensive, including a pre-survey 2 weeks before the event, an on-site survey at the end of the field workshop, and a post-survey 1 month after the event. The evaluations aimed to assess participants' views of ASP and changes after the event and identify network-building opportunities.

These two events with multiple parts initiated the stakeholder engagement effort for the KBS LTAR project and also reflected the assessment process detailed in this paper. Stakeholder engagement efforts have continued. In 2023 a 15-member stakeholder advisory board was formed to provide advice and guidance on ACSE design, suggest and prioritize research efforts, give advice on engagement and outreach activities, and help expand the LTAR stakeholder network. Farmer field days and workshops have been conducted regularly to facilitate emergent project needs such as co-producing project outcomes and research priorities.

1.2 | Social science integration

Before joining the LTAR Network, KBS had a robust social science presence, evidenced by a regional-scale, continuous panel survey of farmers that shaped the BAU design (Beethem et al., 2023; Guo, Marquart-Pyatt, Beethem, et al., 2023). The LTAR Common Experiment design (Liebig et al., 2024) opened new opportunities for transdisciplinary collaboration (Jacobs & Frickel, 2009). KBS LTAR's stakeholder engagement specialist led direct engagement efforts such as contacting stakeholders and facilitating discussions. The KBS social science team focused on reviewing and summarizing the literature and co-developing an assessment protocol informed by best practices in social science survey research methods.

This dual approach, with social scientists and stakeholder engagement specialists in collaborative yet distinct roles, contrasts with Wilmer et al. (2022), where social scientists directly handled engagement and evaluated its effectiveness as insiders. Approaches to stakeholder engagement vary: some prioritize action and mutual learning, fostering active participant involvement, while others maintain researcher-participant boundaries to ensure objectivity. These boundaries, however, are increasingly blending, with growing recognition of the value of collaboration. In transdisciplinary projects, social science engagement can sometimes be mistaken for outreach, undervaluing its specialized theories, methods, and skills. KBS efforts emphasize a commitment to sustained stakeholder engagement and rigorous social science research.

Our team of social scientists, engagement specialists, and natural scientists worked collaboratively to make the engagement efforts theoretically informed and incorporate aspects of social learning (Cundill & Rodela, 2012). The concept describes a collective learning process embedded in joint decision-making and knowledge co-production that emphasizes outcomes such as helping individuals recognize interdependence and differences, constructing a shared understanding of a problem and solution, and forming changes at the individual, network, and society levels (Muro & Jeffrey, 2008; Pahl-Wostl et al., 2007; Reed et al., 2010). The framework predicted that with the representation of diverse stakeholders and intentional dialogues, a shared vision can emerge along with changes in individual perceptions and actions.

This work informed the 2022 survey where we repeated questions about ASP perceptions and assessed behavioral, knowledge, and relationship changes as outcomes of stakeholder engagement events. We also incorporated Reed's theory of participation to conceptualize relationships among assessment measures (Reed et al., 2018). Reed et al. (2018) proposed that a well-designed stakeholder engagement effort in a conducive context (e.g., stakeholder interests) that both manages power dynamics among participants and matches temporal and spatial scales is more likely to deliver beneficial outcomes. This approach shed new light on survey questions and prompted us to examine stakeholder preference as a context indicator and experience as short-term outcomes that affect long-term outcomes.

Together, through the iterative process of designing data collection strategies, including two surveys based on project needs and literature, we explored three key areas: (1) participants' expectations and motivations for the project and events, (2) short-term outcomes including participant satisfaction and perception of the events and researchers, and (3) intermittent outcomes toward long-term changes in practice, trust, and desire to connect, and a shared vision for an aspirational agricultural system of the future.

2 | MATERIALS AND METHODS

We used two surveys to assess the contexts and outcomes of the two stakeholder engagement events hosted at KBS in 2021 and 2022. Social scientists, stakeholder specialists, and project leaders collaboratively developed the surveys. Questions used in the paper are listed in Table 1.

Survey implementation followed guidelines for best practices (Dillman et al., 2014). The survey for the first event was conducted online in the spring of 2021. The stakeholder engagement specialist sent a pre-survey notification to all

TABLE 1 Survey measurements of stakeholder engagement outcomes.

Context and outcomes	Survey questions	Survey year
Participant expectation	What outcomes and outputs would you hope the KBS LTAR program provides over time?	2021
	What motivated you to come to the field workshop?	2022
Participant satisfaction	Please rate your levels of agreement or disagreement with the following statements: researchers genuinely appreciate their insights and experience; I feel engaged through the day; I feel my voice was heard during the discussion; I feel comfortable sharing ideas during the discussion.	2022
	How likely are participants to participate in future KBS events	2022
	Please rate the usefulness of the following sessions	2022
Social learning	Did the workshop help you to build and strengthen relationships with others, learning about other group's vision, values, and way of thinking, recognize a shared vision for the future of agriculture in Michigan, better understand the KBS LTAR project, and better understand measurements and metrics to assess agronomic progress?	2022
	After your involvement in any of the KBS LTAR events this year, how did your knowledge, trust, and interest related to agricultural research change or remain the same?[a]	2021
	Did you learn something new from the workshop?	2022
	Did you meet someone new at the event?	2022
	Did you do something new or different because of the workshop?	2022
ASP perception	How would you evaluate the proposed Aspirational System (5-year rotation and management practices over time) according to the following criteria?	2021, 2022

Abbreviation: KBS, Kellogg Biological Station.

[a]The question used a five-point scale. For analyses, the variable was recoded into a binary variable. people who selected increase "somewhat" to a "great deal" were combined to the category of yes.

participants of the visioning symposium, focus groups, and design teams, followed by an invitation with a link to a Qualtrics survey and a reminder message. The survey for the second event included an online pre-survey, an on-site paper survey administered at the end of the field workshop in 2022, and an online post-survey a month after the event. The pre-post design sought to capture changes in participants' networks, but most of the outcome measures reported in this paper were included in the on-site and post-survey. The on-site survey was a short paper questionnaire to capture participants' immediate evaluation of the event, including the usefulness of various sessions and whether they felt engaged, comfortable sharing ideas during the discussion, and that their voices were heard. The post-online survey measured participants' perceptions of the proposed ASP and other event outcomes. A question repeated in the pre-survey and on-site survey was the extent to which respondents agreed or disagreed that KBS researchers hear and appreciate their insights and experience in the experimental research design.

We conducted independent *t*-tests to compare whether university-affiliated researchers and other participants differed in whether they felt engaged, comfortable sharing ideas during the discussion, that their voices were heard, and how they assessed the ASP treatment. We used paired *t*-tests to compare participants' agreement on whether KBS researchers hear and appreciate their insights and experience before and after the event. We used chi-square analysis to compare expected outcomes and motivations for university-affiliated researchers and other participants. The 2021 survey was anonymous, which prevented us from tracing ASP perceptions of individual stakeholders between the 2021 and 2022 surveys. We compared the 2022 ASP rating with the means from the 2021 survey using one-sample *t*-tests.

3 | RESULTS

The 2021 and 2022 stakeholder engagement events attracted various stakeholder groups. Diverse representation was reflected in the survey respondent profiles (Table 2). The 2021 survey collected 58 valid responses out of 124 invitations. The 2022 survey was sent to 87 individuals. Fifty-one individuals responded to the pre-survey, 50 individuals to the on-site survey, and 37 individuals to the post-survey. More non-profit organizations and agency representatives were present in the 2022 event compared with the 2021 event, while the representation of extension was lower.

The 2022 stakeholder event involved in-person presentations, breakout sessions, and informal networking opportunities. Respondents indicated that they felt engaged throughout the day (mean = 4.5, on a five-point scale), that their voice was heard during the discussion (mean = 4.5), and that

TABLE 2 Respondent affiliation percentages for the 2021 and 2022 stakeholder event surveys.

	2021 Survey	2022 Survey
University-affiliated researchers, staff and students	53%	41%
Farmers	17%	16%
Extension	13%	7%
Agribusiness	6%	6%
Nonprofit organizations	4%	16%
Agencies	4%	14%
Farm advisers	4%	0%

they felt comfortable sharing their ideas during the discussion (mean = 4.5). There was no significant difference in these items between university-affiliated researchers and other participants.

The most useful session to the respondents was the social networking opportunities such as breaks and lunchtime (mean = 9.3, on a 10-point scale), followed by an overview of the LTAR experimental design (mean = 8.7), breakout group discussions on how to measure outcomes of the Common Experiment (mean = 8.7), reflection from farmers, agency, and NGOs (mean = 8.7), and highlights of research results from other projects (mean = 8.2). Respondents were also asked in the pre-survey and the on-site survey immediately after the sessions to indicate whether they agree that KBS researchers hear and appreciate their insights and experiences. Participation in the field workshop day significantly increased individual respondents' ratings from a mean of 3.9 pre-event to a mean of 4.5 on a five-point scale post-event (t-value = −4.315, p-value < 0.001).

3.1 | Participants' expectations and event outcomes

The 2021 and 2022 surveys provided baseline data on what participants expect of the LTAR, as well as the initial impacts of the first events. From the 2021 survey (Panel A of Figure 2), most respondents shared that they expect the KBS LTAR to contribute to conservation and environmental ideas (81%) and inform policies and programs at local and state as well as national and federal levels (71% and 67%, respectively). The majority also expect the LTAR to provide agronomic ideas (62%), as well as opportunities to connect with farmers, agriculture professionals, and researchers (60%). Less than half (48%) expected an opportunity to be involved in research. Researchers and non-researchers do not differ on most of the expectations, except that more researchers (61%) expected to have opportunities to be involved in designing field experiments and interpreting data, compared to 32% of other participants who selected the outcome of engagement ($\chi^2 = 4.37$, p-value = 0.037).

Regarding the outcomes of the first event, 68% of respondents reported their interest in KBS research increased somewhat to a great deal, building a strong foundation for idea sharing and relationship building (Panel B of Figure 2). Sixty-one percent of the respondents reported that their knowledge of agriculture in the Midwest increased after their involvement in the first event. Many respondents (52%) indicated their desire to engage with researchers increased after the first event. A plurality of respondents (38%) expressed that their trust in agricultural research increased somewhat to a great deal. The remaining respondents responded that their trust levels remained the same except for one respondent reporting decreased trust. The findings highlight the gradual increase in trust in research over time, in contrast to the inherent fragility of that trust.

The 2022 survey added more detailed questions regarding participant motivations, expectations, and outcomes. Interest in KBS research and networking opportunities motivated most participants (71% and 68%, respectively) to attend the 2022 stakeholder field workshop day (Panel C of Figure 2). No difference in motivation was found between researchers and other participants. Post-event, participants said that they acquired a more thorough grasp of the KBS LTAR project and its metrics and measures. Respondents also indicated a better understanding of other groups' vision, values, and ways of knowing, building, and strengthening relationships, and started to recognize a shared vision for the future of agriculture in the region. These outcomes reflect ongoing social learning and likely reflect the diverse representation at the event, the presentations from stakeholders, and the opportunities for informal networking.

The 2022 survey measured outcomes differently from the 2021 survey. Almost all respondents (97%) reported having learned something new or having met someone new at the workshop, indicating a benefit of in-person event (Panel D of Figure 2). Taking different actions after the workshop was less common (results not shown), with 35% of respondents indicating that they have done something new or different because of the workshop, among whom 42% were university-affiliated researchers followed by agency, nonprofit, and extension (17%). In addition, 47% of respondents indicated they planned to do something new or different because of the workshop, such as searching for information, developing a new research or policy advocacy project, or trying out a new practice.

3.2 | Perceptions of the Aspirational Cropping System

We measured event participants' views toward the proposed aspirational treatment in both the 2021 and 2022 surveys.

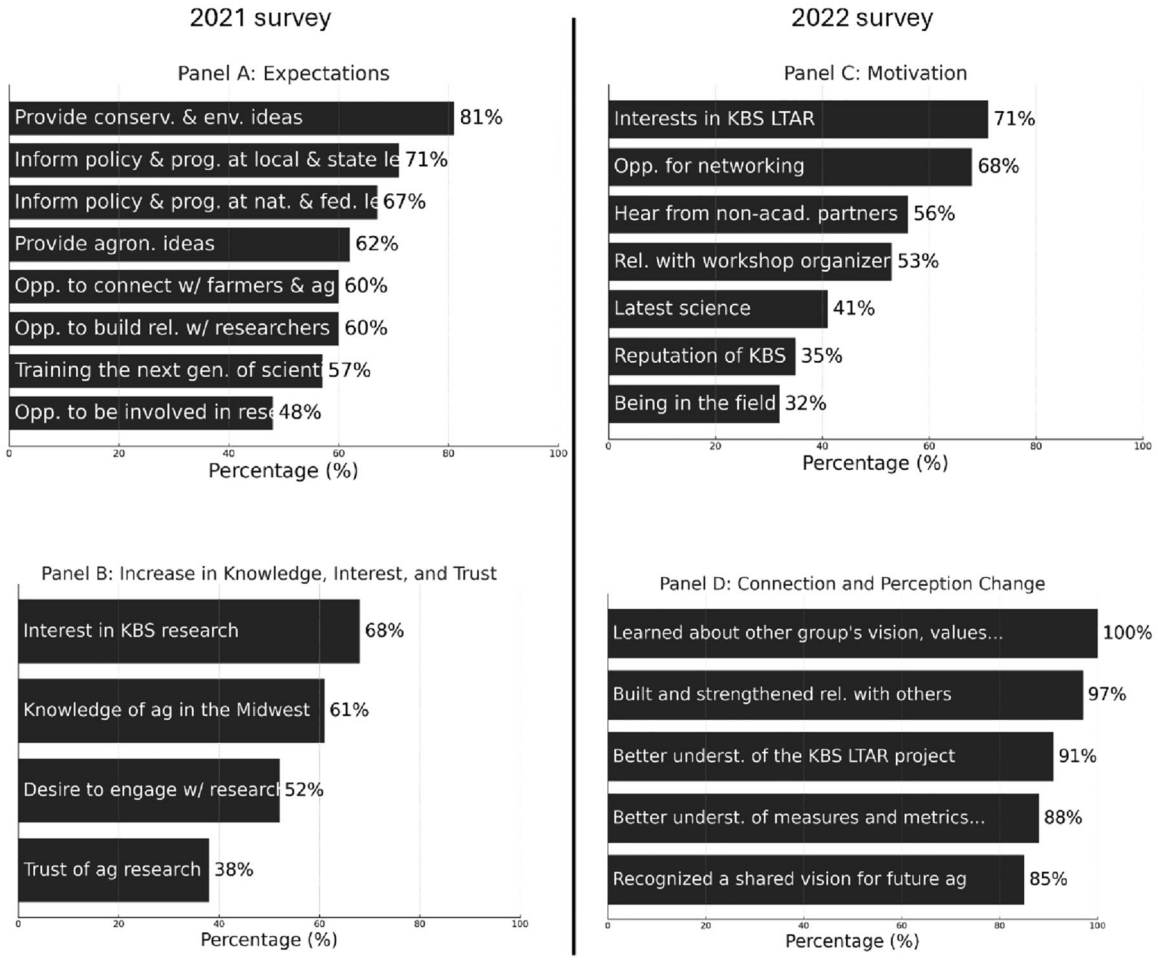

FIGURE 2 Participant expectations and outcomes from the 2021 survey (Panels A and B) and 2022 survey (Panels C and D). KBS, Kellogg Biological Station.

Respondents were presented with a visual depiction of the aspirational system over the 5-year crop rotation along with a description of the crops and associated management practices. They were asked to rate the system on a 1–5 scale according to five adjective pairs: unprofitable to profitable, unmanageable to manageable by farmers, conventional to innovative, limiting to enhancing environmental benefits, and not resilient to resilient. The mean ratings of all adjective pairs passed the midpoint of three, suggesting an overall positive assessment of the ASP treatment (Figure 3). More specifically, respondents generally had positive reviews of the ASP treatment's potential profitability, manageability, innovativeness, ability to enhance environmental benefits, and resilience. This was the case for both the 2021 and 2022 surveys. We found no statistical difference in ratings between university-affiliated researchers and other participants. Using one-sample *t*-tests, participants from the 2022 survey showed significantly higher ratings for enhanced environment benefits, innovation, resilience, and profitability, and significantly lower rating for manageability than the average of the 2021 ratings.

4 | DISCUSSION

Results provide an account of the selection and quantitative measurement of outcomes for stakeholder engagement integrated into the design of an Aspirational Cropping System for the LTAR Common Experiment at KBS. Notably, results highlight the critical role of reciprocity alongside iterative design and assessment in stakeholder engagement. Our findings support the value of co-designing an Aspirational Cropping System and draw attention to what and how to measure the effectiveness of stakeholder engagement.

An important goal of the two stakeholder engagement events at KBS was to understand the collaborative vision of the future of agriculture and use that understanding to co-design the KBS LTAR Common Experiment. Researchers and stakeholders collectively identified the ASP treatment, which reflects a vision of agriculture featuring regenerative practices that maximize nutrient cycling, biodiversity, and climate mitigation, and utilize advanced technologies. Survey results revealed that a diverse group of stakeholders held overall

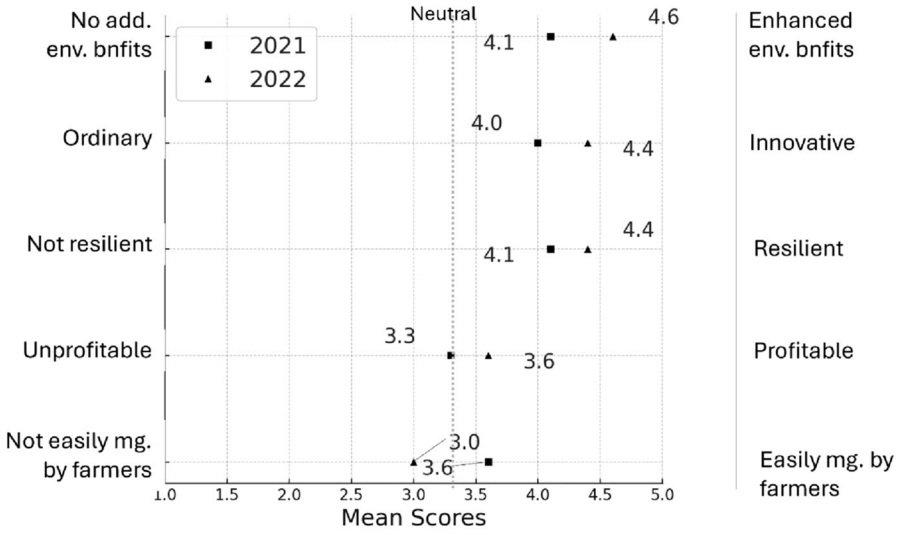

FIGURE 3 Bar graph showing mean score for each ASP criteria and changes between the 2021 and 2022 surveys.

positive perceptions of the ASP treatment. Particularly, to the respondents, the ASP system might not sacrifice profitability. However, respondents to both surveys seem to be more uncertain about the manageability of the proposed cropping system, which is understandable as most ASP practices will add complexity to current farming operations (Roesch-McNally et al., 2018; Van Deynze et al., 2022). A sharp learning curve for a new practice, plus combinations of multiple conservation practices, potential short-term fluctuation in yields and profits, and marginal profitability may create a perception that will hinder its adoption and adaptation.

While meeting project goals, stakeholder engagement should also seek to benefit participants, in line with the reciprocity principle. What benefits can stakeholder engagement events provide to participants? As in other studies, the respondents to our surveys indicated that they particularly value stakeholder events for idea exchange and the opportunity to network with researchers and other stakeholders, which are key elements for social learning (Holifield & Williams, 2019; Jackson-Smith et al., 2018; Wilmer et al., 2022). Many participants came to the events to obtain new conservation and environmental ideas or because they were interested in KBS LTAR research. They left the events with new ideas and increased knowledge about regional agriculture. About two-thirds of respondents selected networking opportunities as their motivation to attend and as an expected outcome of their participation. Respondents rated social network opportunities as the most useful sessions. The finding is consistent with Holifield and Williams's (2019) suggestions of using engagement events as an opportunity for stakeholders to build and strengthen their networks and previous findings on the effects of stakeholder engagement on stakeholder networks (Guo et al., 2024; Luján Soto et al., 2021; Teodoro et al., 2021). Identifying potential benefits before an event can help guide event design and facilitation. Feedback collection using interviewers and open-ended questions at the end of an event can help explore emergent benefits.

Results also reveal that stakeholder engagement can benefit from an iterative design that involves assessment and adjustment. We observed how various survey methods, questions, and timing of survey contacts and follow-ups helped generate information that guided the engagement effort. For example, the 2021 survey identified networking as an expectation of stakeholders. The social science team shared the results with the research team through reports and presentations. The stakeholder expectation was then recognized as a goal of the 2022 event (to build and strengthen partnerships) and communicated to all participants. Breakout discussion sessions and informal social time, such as coffee breaks and lunchtime, were incorporated into the 2022 event to foster interactions and dialogues. The articulation of stakeholder engagement goals signals an evolved understanding of stakeholder engagement and allows a more systematic approach to its execution. The 2022 follow-on survey then assessed how these efforts helped to facilitate emergent social networks, which will guide future relationship-building efforts (Guo et al., 2024).

Last, social scientists in the research team took a position outside of the engagement effort, conducting the assessment as observers and facilitating implementation and reflection. We believe that transdisciplinary projects should invest in both the work of engagement and social science research. Approaches will, of course, look different for different projects. For example, the USDA Agriculture Research Service Central Plains Experiment Range, a LTAR network location, Collaborative Adaptive Rangeland Management experiment used a more integrated approach, where social scientists simultaneously implemented and assessed stakeholder engagement (Wilmer et al., 2022). In contrast, we

distinguished between social science and stakeholder engagement practices, reflecting our tendency toward positivist research methods emphasizing objectivity and empirical evidence. We believe transdisciplinary projects should recognize the diversity of approaches to stakeholder engagement and social science research and value the skills and expertise required in stakeholder recruitment, facilitation, and retention (Canfield et al., 2022; Neef & Neubert, 2011; O'Connor et al., 2019; Sterling et al., 2017). With available resources and a history of collaboration, KBS LTAR is poised to implement a collaborative team approach, bringing together stakeholder engagement specialists with biophysical science expertise to manage outreach, social scientists to contribute to strategy development, literature synthesis, and evaluation, and natural scientists to also play an active role in ensuring the science of the experiment is robust and innovative. Project needs and resources, the interests and expertise of social scientists, and the history of collaboration should guide the choice of approach.

A few limitations of this study are worth noting. First, the sample was self-selected by stakeholders willing to participate in stakeholder events and surveys. Second, more university-affiliated stakeholders completed the surveys than producers and agricultural professionals. And finally, the results cannot be generalized to all stakeholder groups of the KBS LTAR region nor split by stakeholder groups due to sample size. We also noticed a decline in response rates from pre-survey to post-survey. Although a social scientist presented a snapshot of the 2021 survey results to stakeholders at the 2022 event, the benefit of participating in the social science component may not be clear to the stakeholders, calling for improved design and incentives in future work. Given concerns about unintentionally suppressing response rates, we did not track participant information in the first survey, missing opportunities to compare ASP perceptions across years and participants. Building on the lessons learned from the 2021 and 2022 surveys, future assessment efforts should be designed to collect data that can be used to test hypotheses and advance the propositions about successful engagement. Last, we lacked details and contextual information from in-depth, qualitative assessments. Wiek et al. (2014) described how qualitative evaluation can capture unintended social outcomes that are less tangible and quantifiable. Key informant interviews or focus groups can explore reasons and nuances reflected in the quantitative data. A more comprehensive iterative assessment protocol should include qualitative methods.

The cropland Common Experiment at KBS, which is called the ACSE, started in 2022. The first 5 years of KBS LTAR aim to generate site-based research and the capacity to transfer findings to regional farm settings (Robertson et al., 2024). Stakeholder engagement has been recognized as integral to the project as manifested by investment in personnel and annual field events. The establishment of the advisory board in 2023 institutionalized stakeholder engagement within the project. The next step is to examine the evolution of perceptions among event participants using panel design and among the broader farm population in the area. Key informant interviews and focus groups with the broader community will provide a more detailed understanding of how diverse stakeholders envision the future of agriculture. It may be interesting to connect cross-site comparisons to reveal the impacts of contexts on stakeholder engagement. There are unique opportunities at KBS and other LTAR sites to study the long-term effects of stakeholder engagement and how future perceptions evolve.

5 | CONCLUSION

Using reciprocity and iteration principles, we assessed how stakeholder engagement events at KBS met with participants' expectations and how stakeholders viewed the co-produced ASP system. The idea that successful strategic stakeholder participation should include setting goals and monitoring using reciprocity and iteration principles has important implications for long-term, mission-driven agricultural projects. The long-term success of engagement involves resources to clearly define the benefits for stakeholders and track outcomes over time. Quantitative and qualitative social science research methods can help a project detail its goals for stakeholder engagement. The process is not linear, nor should it be a one-time effort, as formative assessment requires ongoing adjustments. Biophysical scientists need not become experts in stakeholder engagement. Instead, they can utilize the expertise of stakeholder engagement practitioners and social scientists through a co-production process. With a heightened focus on intentional stakeholder engagement, professions dedicated to networking, facilitation, and communication are adapting and evolving. Being intentional, proactive, reflective, and adaptable will model the principle of reciprocity and lead to more inclusive engagement.

AUTHOR CONTRIBUTIONS

Tian Guo: Conceptualization; data curation; formal analysis; methodology; writing—original draft; writing—review and editing. **Sandra Marquart-Pyatt**: Conceptualization; data curation; project administration; writing—review and editing. **Tayler Ulbrich**: Visualization; writing—review and editing. **Julie E. Doll**: Data curation; project administration; writing—review and editing. **Brook Wilke**: Project administration; writing—review and editing. **G. Philip Robertson**: Funding acquisition; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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