



Effective stakeholder engagement for decision-relevant research on food-energy-water systems

E.J. Trammell^{a,*}, J.L. Jones-Crank^{b,1}, P. Williams^c, M. Babbar-Sebens^d, V.H. Dale^{e,f}, A.M. Marshall^g, A.D. Kliskey^c

^a Environmental Science, Policy & Sustainability, Southern Oregon University, 1250 Siskiyou Blvd, Ashland, OR 97520, USA

^b School of Sustainability, Arizona State University, USA

^c Center for Resilient Communities, University of Idaho, USA

^d School of Civil and Construction Engineering, Oregon State University, USA

^e Department of Ecology and Evolutionary Biology, University of Tennessee, USA

^f Oak Ridge National Laboratory, USA

^g Department of Sociology, University of Illinois, Urbana, Champaign, USA

ARTICLE INFO

Keywords:

Accountability
Diversity
Flexibility
Theory
Trust

ABSTRACT

Given the integrated nature of food-energy-water systems (FEWS), stakeholder engagement is central to developing solution-oriented projects. However, effective engagement requires substantial time and resources, by both the organization conducting the project and the stakeholders themselves, making effective engagement challenging for many projects. To help teams prioritize, prepare, and sustain stakeholder-engaged environmental projects, we propose a methodological foundation for effective engagement based on six gears: diversity, listening, value, trust, accountability, and flexibility/adaptability. The application of these gears is demonstrated using a set of case studies in Arizona, Idaho, Mexico, and Guatemala. In practice, incorporating all the gears during stakeholder engagement can be challenging. This framework can help teams implement and foster more sustained, comprehensive, robust, actionable, equitable, inclusive, and timely engagement, processes, and outcomes.

1. Introduction

Sustainability requires effective participation of all people and groups who may be positively or negatively affected by changes in the biophysical and social systems of which they are a part. This type of involvement is often referred to as stakeholder engagement (Haddaway et al., 2017). In this paper we adopt Haddaway et al.'s definition of 'stakeholder' as "Anyone or any entity who can influence, or will be affected by the issue, set of findings, or action." (Haddaway et al., 2017) However, we acknowledge that Tribal Nations prefer designations such as 'rightsholders' in reference to the sovereign rights that Tribal Nations hold. Recent research on progress toward sustainability has focused on the nexus between food, energy, and water systems (FEWS) (Weitz et al., 2017; Ojha et al., 2022), but guidance for effectively involving stakeholder and rightsholders in FEWS projects specifically has been limited

(McGreevy et al., 2022; White et al., 2017). Involving stakeholders and rightsholders in FEWS research is particularly important, as the interdisciplinary nature of the domain requires a wide range of knowledge for effective system analysis, and their involvement increases the development of usable science that is relevant to implement in practice (Holmatov et al., 2023; Wahl et al., 2021; Hoolohan et al., 2018).

To investigate how well FEWS researchers engage stakeholders, our research coordination network (RCN) conducted a meta-analysis of 489 FEWS papers published between 2015 and 2023 and discovered that only 90 (about 18 percent) included stakeholders in their project (Williams, 2025). We characterized levels of engagement using the International Association of Public Participation (IAP2) scale, which ranges from inform to empower; representing a continuum of increasing levels of involvement and ownership over the process by stakeholders. Our analysis revealed that 38 % of the papers did not meet the lowest

* Corresponding author.

E-mail addresses: trammelle@sou.edu (E.J. Trammell), ljonescrank@uwaterloo.ca (J.L. Jones-Crank), paulawilliams@uidaho.edu (P. Williams), meghna@oregonstate.edu (M. Babbar-Sebens), vdale@utk.edu (V.H. Dale), amarshll@illinois.edu (A.M. Marshall), akliskey@uidaho.edu (A.D. Kliskey).

¹ Current affiliation: School of Environment, Resources, and Sustainability, University of Waterloo.

threshold of engagement as defined by IAP2 because the purpose was solely to gather data from stakeholders, 3 % met the inform definition, 17 % consult, 14 % involve, 12 % collaborate, and 6 % empower (Table 1). These data suggest that FEWS manuscripts do not reflect a practice of robust stakeholder engagement. Of the 90 papers that engaged stakeholders, four engaged tribal or indigenous representatives, also suggesting that FEWS researchers are not routinely engaging indigenous representatives.

Other research areas such as sustainability (Norström et al., 2020), water service and policy (Landriani et al., 2022), adaptive environmental management (Cosens et al., 2021), and long-term ecological studies in oppressed communities (Grove et al., 2024) have a more robust and developed practice and literature on stakeholder engagement. This paper summarizes the experiences and practice of FEWS researchers who have engaged stakeholders and identifies six practices that enhanced the experience of stakeholders in FEWS and motivated them to remain engaged, which we argue is more effective engagement. We define effective engagement as involvement of stakeholders in the project to an extent that they find value in participation and their involvement enriches the process for researchers (Oates and Dodds, 2017). However, the level of involvement is likely to vary depending on the project. Additionally, in combining the expertise of numerous FEWS scholars and the learnings from, and application to, multiple case studies of FEWS research, this paper provides a guide of six practices that can be implemented for enhanced stakeholder engagement.

Stakeholder engagement in FEWS poses unique challenges. Ideally, FEWS stakeholder engagement should be diverse and include representatives from across all three resource sectors (food, energy, and water); from different economic, governance, cultural, and ethnic sectors (including municipal, industrial, environmental, agricultural, and justice organizations); and from different levels of operation (user, operational, policy/advocacy, and informational levels) (Bieliński et al., 2019; Hargrove and Heyman, 2020). The different languages used by those involved in each of the three systems, different values and interests of project organizers and stakeholders, and different temporal and geographic scales of interaction among the systems all contribute to those challenges. Stakeholder engagement in projects can range from issuing a questionnaire to gathering data through asking stakeholders to identify the problem to be addressed in the project and placing the decisions and outcomes in the hands of stakeholders as reflected in the IAP2 spectrum (Table 1). Effective stakeholder engagement, at a minimum, should endeavor to (a) understand the different perspectives of stakeholders interested in and affected by the project scope and activities, and (b) consider those perspectives in achieving intended outcomes of the project; consistent with the IAP2 level of consulting. More involved levels of stakeholder engagement than this minimum are rarely practiced in FEWS research; of 483 FEWS manuscripts published between 2015 and May of 2023, 86 engaged stakeholders and 46 % of those did so for the purpose of data gathering (Williams, 2025). Ideally, stakeholders are empowered when they identify problems to be addressed in the project, and the final decisions or solutions are placed in their hands because solutions identified by FEWS researchers will be implemented, if at all, by stakeholders. While significant effort has focused on understanding the role of stakeholders in FEWS, many

project organizers recognize the need for better engagement efforts and for fundamental research on the stakeholder engagement process itself (White et al., 2017). Addressing these needs allows research to be more meaningful and important to the stakeholders and the results to be more readily accepted and implemented by the relevant communities (Sterling et al., 2017).

This study defines key components of engagement as part of a National Science Foundation (NSF) funded research coordination network RCN called ENGAGE INFWS. One hundred twenty-two participants were invited to assemble lightning talks that highlighted important lessons and challenges in working to engage with stakeholders in their FEWS projects (see Supp A for links to these talks). From those presentations, one of the working groups involved in our RCN distilled and then debated the important theoretical and methodological approaches relating to engagement in FEWS systems; we reviewed each of the lightning talks and noted common themes regarding best practices for stakeholder engagement in FEWS research. Once consensus was reached about key themes, we then reviewed stakeholder engagement literature to ground the observations in theory. This process identified six gears of engagement: diversity, listening, value, trust, accountability, and flexibility/adaptability and defined a framework in which they can be incorporated into FEWS projects. This framework is exploratory in nature and provides an initial approach that can be tested through future analysis. This Perspective discusses the gears, strategies for implementing them, and reviews illustrative examples from case studies in Arizona, Idaho, and the agricultural landscapes of Mexico and Guatemala to consider the obstacles and benefits of using the six gears for effective stakeholder engagement in FEWS projects. Reflecting on this framework through the case studies helped us identify several challenges, practical considerations, recommendations, and next steps for effective engagement of stakeholders. This perspective also suggests some next steps for testing the applicability of the six gears in practice.

2. Gears of engagement

2.1. Six gears of effective stakeholder engagement

We propose six gears as essential for effective stakeholder engagement in FEWS projects. While each gear is important, they are not mutually exclusive; each gear is influenced by the others (Fig. 1). We describe each of the gears in detail below, arguing that collectively these six gears are an essential part of identifying and addressing the goals of effectively engaging stakeholders, particularly in FEWS research.

2.2. Diversity

Diversity of stakeholders refers to the intentional inclusion of a breadth of stakeholders across multiple sectors, interests, areas of expertise, and operational levels. Diverse stakeholder groups include all actors who affect or are affected by the systems of interest (Lewis et al., 2012; Nutt and Backoff, 1992). The diversity gear can increase understanding of the system by providing a broad and varied perspective on problem framing (Sušnik, 2018; Trabucco, 2018), allowing for a more nuanced understanding of the dynamics of the system (Hoolohan et al.,

Table 1
Description of engagement levels in IAP2 spectrum of public participation.

IAP2 Spectrum of Public Participation					
Engagement level	Inform	Consult	Involve	Collaborate	Empower
Description	Provide stakeholders with balanced and objective information to understand the problem, opportunities, or solutions.	Obtain stakeholder feedback on analysis, alternatives, or decisions.	Work with stakeholders throughout the process to address concerns and consider stakeholder aspirations.	Partner with stakeholders in all aspects of the decision process, including in the development of solution options and in deciding the preferred solution.	Place the final decision in the hands of the public.



Fig. 1. Gears of effective stakeholder engagement in FEWS, with each gear influencing, and being influenced, by the other gears.

2018; Bisaro et al., 2014), creating more disparate and inclusive solutions and strategies (Bisaro et al., 2014; Green et al., 2017), and bringing consensus across multiple values to improve policy and management (Bielicki et al., 2019). Project organizers' understanding of the problem context should be used to make decisions on which actors are important to engage, including the intentional involvement of marginalized communities, and the stakeholders' perspectives as to who needs to be engaged; the final choice of exactly who to include requires wise and ethical judgment on the part of organizers and stakeholders (Bryson, 2004). Engagement of stakeholders in the process can be incentivized, such as by knowledge exchange and by paying stakeholders for their time in recognition of the value of their knowledge and constraint on their time, although incentives vary by professional culture (Harris and Lyon, 2013); see "value" section below.

2.3. Listening

Listening is an essential ongoing aspect for effective engagement (Scholes and Clutterbuck, 1998). Nevertheless, the majority of organizational resources devoted to public communication (about 80 %) are not focused on listening but rather on speaking to stakeholders (Macnamara, 2020). Listening requires an open, empathic mind as well as attention to language and mode of communication, especially when working with diverse stakeholders (see above). Effective listening necessitates paying attention not only to what is said, but also to nonverbal behavior, avoiding distractions, clarifying understanding by asking meaningful questions, providing feedback, and responding in a clear and empathetic manner. Listening to diverse stakeholders involves awareness of their cultural background and the use of local language. Successful listening includes inviting stakeholders to comment on all

aspects of the process, involving stakeholders in identification of values and the meaning of "success," and creating means for stakeholders to share expectations, values, and understanding (Scholes and Clutterbuck, 1998). Ferguson et al (Ferguson et al., 2017). found that stakeholders were most engaged when they personally felt valued and that their opinions were heard and represented in the research. Listening well can also help avoid conflict and misunderstanding. Lyndon Johnson famously said, "If you're not listening, you're not learning" and commented that the most important thing said is often the last words spoken.

2.4. Value

Clearly identifying and defining the benefits of participating in the engagement process for all stakeholders is essential (Chachine, 2022). Assuring stakeholders of the benefits from their participation increases support, enthusiastic involvement, and retention over the course of a project (Kliskey et al., 2021). Stakeholder values, that is the importance, worth, or usefulness of participation, are often used to define system parameters and to capture social preferences, but the inverse (i.e., what value stakeholders take away from the process) is critical for effective stakeholder engagement. We propose that value to stakeholders can be *individual*, meaning that each stakeholder finds personal value in participating; *societal*, referring to how participation benefits the larger community and future generations; or *institutional*, where the value is primarily in support of stakeholders performing their role in the FEW system (e.g., directly benefits them in their job). Assumptions about the value to stakeholders are often confirmed, especially via creation of a collaborative model like that of Basco-Carrera et al (Basco-Carrera et al., 2017). or an exercise like social network analysis (see (Krupa et al., 2018) for an example). Yet, when assessed post-engagement, many

stakeholders suggest the value to them was more individual than institutional (Ferguson et al., 2017; Trammell et al., 2021). Specifically, Ferguson et al. found that stakeholders valued the engagement process because it strengthened relationships, helped them understand other users' values, and allowed them to personally learn and grow (Ferguson et al., 2018). Although these benefits could lead to institutional value, unless there is clear linkage to a specific agency, translation of the shared learning into management or policy actions is limited (Polk, 2015).

2.5. Trust

Trust is the most essential and the most challenging aspect of successful community and stakeholder engagement (Kliskey et al., 2021). The gear of building trust can be defined as confidence of stakeholders in the engagement process and in project leaders. Trust is a measure of conviction in the reliability and truthfulness of information and in the ability for the process to achieve desired results (Kliskey et al., 2021; Asante Boadi et al., 2019; Kliskey et al., 2023). Trust is essential for the process to fulfill its purpose in guiding decisions toward improved conditions and for delivering outcomes with value (Dale et al., 2019). In FEWS projects, trust occurs at different levels - trust is essential between project leaders and stakeholders and should be reciprocal, while trust is also necessary among individual stakeholders within a diverse body of different stakeholders. For example, an important element of trust is to provide truthful information among participants and not violate the trust of other participants by misquoting them or misusing their words or knowledge, especially in the context of transdisciplinary teams. Care is needed to ensure that trust is developed not only among the people involved in a project, but also with regard to the data used or generated by the project, the engagement and research processes used, and the outcomes and deliverables that emerge from a project. Building trust with stakeholders within collaborative governance structures is a foundational element for adaptation to occur and for overcoming barriers (Jones and White, 2022). Trust, while a critical facet, takes time and may rely upon timelines beyond the predetermined project dates, yet is closely linked to relationship building (Kliskey et al., 2023; Reed, 2008). While fostering trust in the engagement process is considered important, an argument can be made that trust building is a necessary precursor to collaboration (Reed, 2008). "Trust is shown to be built by having an awareness of others, prior experience of working together, norms of cooperation, and sanctions exerted on those who might transgress norms of behavior" (Harris and Lyon, 2013).

2.6. Accountability

In FEWS projects, organizers must think beyond the actors and institutions to whom they are normally accountable in their project activities. The gear of accountability means that a group or organization can make reasonable demands on project organizers and expect to have them met (Parker and Crona, 2012; Miller, 2001; Mitchell et al., 1997). For FEWS researchers, those groups normally include their academic departments and the universities that employ them, their wider academic disciplines and research communities, and their funders (Parker and Crona, 2012). Partnerships in which stakeholders help formulate project questions and receive information that might solve real-world problems can help speed the adoption and diffusion of innovations (Rogers, 2003), as well as provide the basis for policy-making and collective governance over shared resources (Parker and Crona, 2012; Guston, 1999, 2001; Cash et al., 2003). However, the mechanisms for holding FEWS project organizers accountable to stakeholders are less clear. Mitchell et al. (1997) claim that organizers' accountability to stakeholders depends on the importance or *salience* of the stakeholder. Stakeholders' salience rests in the power to impose their will on the project organizers; whether their demands seem legitimate under the circumstances; and the urgency of the stakeholders' interests (Parker

and Crona, 2012; Mitchell et al., 1997). The more salient the stakeholders are across these dimensions, the more likely the FEWS organizers are to meet their needs by prioritizing stakeholders' expectations and demands (Mitchell et al., 1997). By including a diversity of stakeholders within the engagement, there may be opportunities for historically marginalized groups to have their expectations and needs addressed by the researchers. Organizers can build motivation for ongoing accountability by including stakeholders in formal structures, such as advisory committees (Parker and Crona, 2012), by providing them with regular reports and access to data, and by encouraging feedback from stakeholders.

2.7. Flexibility/adaptability

Flexibility or adaptability was identified as an important gear by all lightning talk participants. Flexibility makes projects more responsive and/or relevant to stakeholders. RCN participants defined flexibility broadly including changing the focus of their projects to meet stakeholder needs, responding to criticisms of data used in modeling, increasing options for stakeholders to attend meetings, and expanding stakeholder participants to include key organizations that were not initially included. Flexibility is critical to building models that can accommodate differing water, energy, and food regimes or differing qualities of data (Daher et al., 2017; Shinde, 2017), when including indigenous peoples in rightsholder engagement (Chief et al., 2014, 2016; Whyte, 2014), in developing solutions (Gupta, 2017), in responding to local priorities (Coates and Tapsell, 2019), and in decision-making to address uncertainties (Creed et al., 2018), among others. This approach to flexibility and adaptation mirrors the business concepts of pivoting, strategic change, and creative revision. Kirtley and Mahoney (Kirtley and O'Mahoney, 2020) and Hampel et al. (Hampel et al., 2020). defined pivoting similarly as changing business strategy or correcting course following feedback suggesting a change. In business, there are often financial signals for the need to pivot such as loss of market share. There are rarely such signals in FEWS projects, and less motivation to make changes as well. However, pivoting or strategic change is an important strategy for aligning projects to stakeholder needs and can increase project relevance to the region of study, increase accuracy of data used in projects, and result in interaction among stakeholders and organizers that promotes effective engagement (Kliskey et al., 2023).

3. Case studies

Once these six gears were defined, we explored the practical considerations for effective engagement by examining the gears within a set of three previously published FEWS nexus case studies. We did this to illustrate Ostrom's Law: "a resource arrangement that works in practice can work in theory" (Ostrom, 2008; Fennell, 2011). These case studies describe the challenges during, and successes in, considering the six gears for stakeholder engagement across three different studies (Box 1). Our case studies focus on a) the use of water, nutrients, and energy in Idaho, b) an urban FEWS in Arizona, and c/d) agricultural landscapes of Mexico and Guatemala. Box 1 provides an overview of each case study project.

3.1. Magic Valley Idaho (case study A)

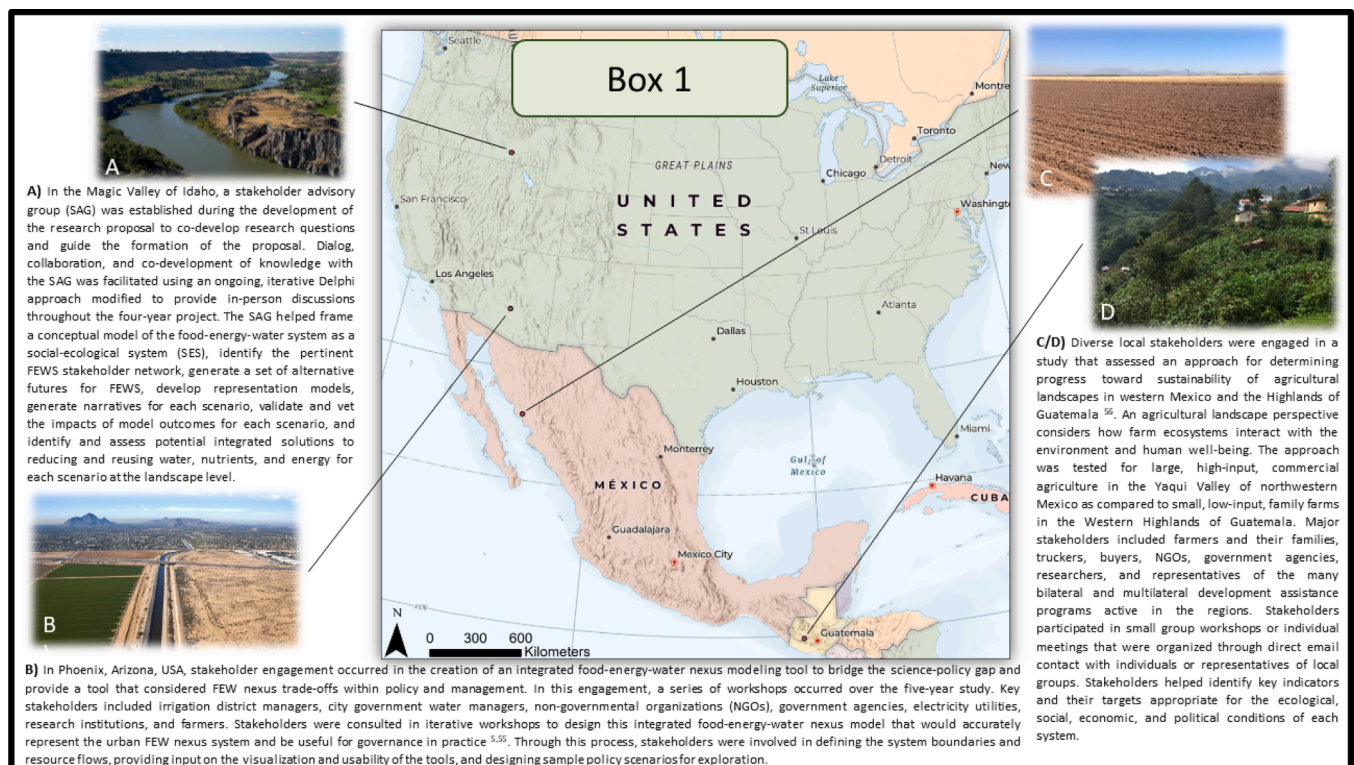
In the Magic Valley, organizers developed long-standing and trusted relationships with many members of a stakeholder advisory group (SAG). The SAG identified and prioritized issues and decisions that would need to be made in their region over a 30-year time period. Unsurprisingly, stakeholders identified water availability and water quality as most important issues; followed by managing population expansion through restriction of urban growth into agricultural lands; reservoir capacity; aquifer recharge; and conversion of agricultural, dairy and

industrial by-product to value-added products. Five different future scenarios were then collaboratively constructed and visualized for the region with stakeholders identifying timeframes for the occurrence of the issues they had identified and resulting biophysical and policy responses (Kliskey et al., 2023). To assure that stakeholders were heard correctly and had their perspectives and interests incorporated into each exercise during a workshop (*listening*), organizers employed a technique known as the 4 Cs: clarification, compliments, concerns, and changes at the conclusion of each section of the workshops. Stakeholders readily corrected any mistakes they perceived had been made, leaving researchers with the impression that the technique worked. *Diversity* was incorporated by inviting stakeholders and rightsholders from different sectors, backgrounds, genders, and ethnicities. The project struggled to maintain the participation of two underrepresented groups - the Native American participants and an organic farmer. However, the team was able to partially address the limited participation by having the Native American participants engage remotely and asynchronously.

Stakeholder *value* was assessed formally, through post-workshop surveys, and informally through personal communication. Formally, stakeholders expressed gaining individual and institutional value through the representations of potential futures (Cronan et al., 2022). The creation of a Magic Valley FEWS Atlas, which visualizes these fu-

culture of respect and *trust*. *Trust* building required an iterative, cumulative, and open set of discussions over four years through 10 workshops (Kliskey et al., 2023).

Accountability was addressed through making stakeholders crucial in developing different future scenarios and incorporating their comments on data sources and reports, which shaped a collaborative set of final outcomes. As examples of input, stakeholders criticized the data used by researchers to estimate the number of cows and amount of milk produced in the region. Stakeholders expressed frustration with researchers' assumptions that, with additional precipitation, increased agricultural production would follow because there was no more agriculturally-suitable land and corrected researchers' assumptions about water rights. As a result, organizers *pivoted* to more accurate and robust datasets, corrected assumptions about water rights and water use, identified areas where significant change in land use would likely occur, and identified indicators that were of the highest importance to the stakeholders resulting in a set of possible futures and solution suites to waste reuse in the linked food, water, and energy systems (Kliskey et al., 2023). In these ways, and many more, stakeholders contributed significantly to organizers' understanding, modeling, and scenario building of the system.



tures, provided social and institutional *value*, especially for rural development organizations. Through personal communication, it was clear that stakeholders derived *individual value* from the engagement process, especially as the COVID-19 pandemic hit mid-study, since stakeholders stated they were better prepared for the impacts of the pandemic as a result of the activities envisioning potential futures. *Trust* was established both through a key stakeholder who had prior relationships with most other stakeholders and through a set of relationships between stakeholders, rights holders, communities, and organizers; that is, the act of engaging with one another was a process of learning rather than being purely outcome driven. This stakeholder process emphasized a set of relationships and their contribution to a

3.2. Phoenix Arizona (case study B)

In Phoenix, stakeholder engagement occurred in a project to design an integrated food-energy-water nexus modeling tool to bridge the science-policy gap (White et al., 2017). The purpose of the engagement was to bring together experts and decision-makers to contribute knowledge towards the tool design and to provide insight on tool components that would be most useful for decision-makers in practice (White et al., 2017). The outcome from this engagement resulted in an integrated model including water systems, energy systems, and an

agro-economic model, a user-friendly interface through modeling visualization techniques, and a series of scenarios with policy levers that could be used to demonstrate how different policy decisions would affect the three nexus systems. The inclusion of a *diverse* group of stakeholders enhanced the project team's understanding of interactions among the FEWS and key drivers of change, and they made it more likely that effective solutions were implemented (White et al., 2017). This group included participants from across the public, private, and non-profit sectors in the food, energy, water, and environmental domains. However, the team struggled to recruit some underrepresented stakeholders, such as Native American tribes due to challenges with institutional *trust*. *Listening* was employed by providing ample time and space for stakeholder responses and feedback on the model throughout four phases of the model development. Stakeholder input was then incorporated into the model and re-presented to the stakeholders, demonstrating the organizers' commitment to *listening* and incorporating stakeholder perspectives into the process and model product (White et al., 2017). Stakeholders expressed gaining individual and institutional *value* as they participated in the stakeholder engagement in a Decision Theater—an interactive and immersive space with 260° screens that facilitate technological visualization, stakeholder collaboration, and decision support (Mounir et al., 2019). This approach provided stakeholders with the *value* of experiencing the state-of-the-art facility, workshoping challenges for real-world decision-making, and having opportunities to network with fellow stakeholders. Engaged participants acknowledged that participating was informative and useful for them in their jobs as they learned about FEWS nexus interactions and engaged with the tool (White et al., 2017).

Building *trust* in the Phoenix case study began before the project took place through events and previous stakeholder engagement opportunities with the Decision Center for a Desert City, a research center at Arizona State University that focuses on advancing knowledge about decision-making for water sustainability under the uncertainty of climate change (<https://sustainability-innovation.asu.edu/dcdc/>). With over 10 years of engagement opportunities prior to the project in this case study, stakeholders had built *trust* from previous activities, and that trust was sustained through iterative and open discussions over the five-year duration of the project (White et al., 2017). *Accountability* in the model-building process included stakeholders who participated in workshops where organizers and stakeholders shared information about data and modeling efforts; organizers revised the model based on input from stakeholders. *Flexibility* was implemented by incorporating stakeholder feedback into the model and by adjusting the format of the stakeholder engagements. Stakeholders provided data and recommended policy scenarios that were used to adapt the modeling and user interface of the model, demonstrating adaptability in project outputs through the iterative updates to the model (White et al., 2017; Mounir et al., 2019). Beyond the model itself, organizers became flexible in their stakeholder engagement format during the COVID-19 pandemic, adjusting two rounds of workshops to be conducted virtually; this *flexibility* in format allowed different stakeholders to participate who were not able to attend in-person meetings. Through the application of these processes, participating stakeholders contributed greatly towards the development of a context-specific integrated model for the food-energy-water nexus.

3.3. Western Mexico and the highlands of Guatemala (case studies C & D)

A variety of stakeholders were engaged in the Mexico and Guatemala case studies. Effective *listening* resulted from much time being used to hear what was said, multiple means for stakeholders to communicate, and having a *diverse* team so that notes could be compared and consolidated (Dale et al., 2020). Aspects of the agricultural landscapes of western Mexico and the Guatemalan Highlands important to the stakeholders were determined using a structured assessment framework (Dale

et al., 2019) that asked stakeholders to identify essential features of the landscape and determine steps to be taken to attain or maintain beneficial conditions. Important aspects for diverse stakeholders of the western Mexico systems included high agricultural production, conservation of non-renewable resources such as soil and water, quality of life (which consists of health, food security, employment, and household income), and crop and native plant diversity (Eichler et al., 2020). Similarly, important aspects for the Western Highlands were improvements in nutrition, poverty reduction, and secure, gainful employment as well as conservation of natural resources (forests, soils, and water) (Kline et al., 2020).

A key *value* that the Guatemalan stakeholders gained from the engagement process was affirmation of the cultural practices of indigenous people and promotion of traditional knowledge in concert with improved seeds and means of dealing with insects and diseases. A *value* important to the Mexican stakeholders was the need to make information available to farmers, farm programs, and agencies so that agricultural practices can be improved for example by crop rotation, use of chemicals, and irrigation. Recognition of the need for technical assistance at many levels was also of great *value*.

A major lesson from the study of agricultural landscapes in those regions was the importance of building transparency and *trust* (Dale et al., 2019). Local contacts were necessary to build *trust* and establish and maintain ongoing interactions with diverse stakeholders, which require much effort over extensive time periods that can be longer than the duration of a typical project. The assessment approach applied to agricultural landscapes in Mexico and Guatemala was designed to be an ongoing process (Dale et al., 2019). Ideally, the iterative effort should provide a means to measure progress toward sustainable landscapes; and changes in management practices and indicators are regularly and systematically reevaluated and adapted to optimize outcomes. Hence long-term support of stakeholder engagement in the approach would build capacities of local community members and other stakeholders, so that they can apply, learn from, and continually improve resource management practices over time (Dale et al., 2020). *Flexibility* incorporated into an iterative process was also a major aspect. The approach was meant to help stakeholders identify and seek improvements in practices that impact their lives. Hence the outcomes and approaches were specific to the needs and opportunities of each landscape. As more was learned about each context, the approach was adapted to those conditions.

4. Synthesis

The three case studies illustrate the way each of the six gears can contribute to effective stakeholder engagement in unique ways and in supporting different engagement levels (Fig. 2). The synthesis figure shows the interdependence among the six gears and illustrates that higher levels of IAP2 engagement required deployment of more of the gears. For example, in the Magic Valley of Idaho case study, the development of researcher-stakeholder *trust* and placing importance on *accountability* of the researchers contributed to engagement at the “Collaborate” level for the Magic Valley FEWS Atlas development. *Diversity* led to more robust integrated solution suites (Williams et al., 2023) in each of the co-developed scenarios and was instrumental in empowering stakeholders (Kliskey et al., 2023). For the Phoenix Arizona case study, the emphasis on *listening* during the early phases of model development contributed to engagement at the “Involve” level, while listening in later phases of model development and revisions contributed towards engagement at the “Collaborate” level as stakeholder knowledge was incorporated back into the modeling tool (White et al., 2017; Guan et al., 2020). *Accountability* through the iterative process of revising the model based on stakeholder input contributed towards engagement at the “Collaborate” level, while the *flexibility* that came from this model evolution, in addition to flexible formats for engagements, contributed towards the “Collaborate” and “Empower” levels.

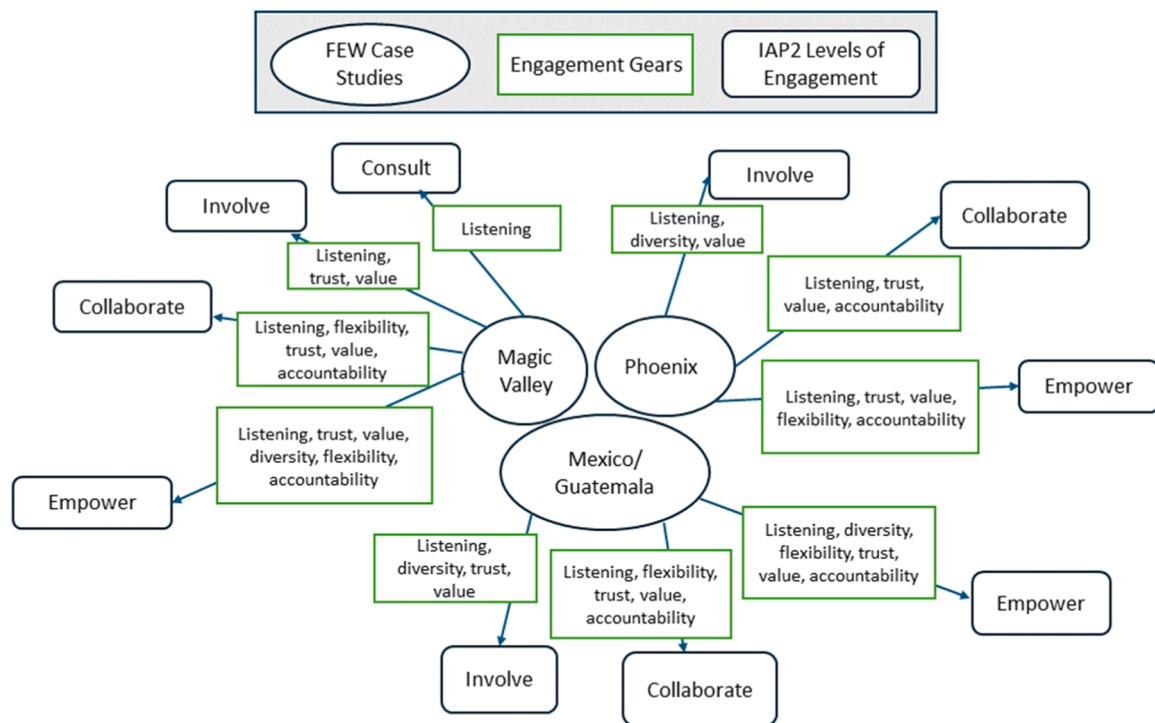


Fig. 2. Illustration of the levels of engagement in each case study and the perceived contribution of each of the gears to the IAP2 levels of engagement. The lower levels of IAP2 engagement were not employed in our case studies.

For the Mexico and Guatemala case study the incorporation of *flexibility* into the outreach process led to engagement at the “Involve” level of engagement for some stakeholders and at the “Empower” level for other stakeholders who were able to identify and improve farming practices in an impactful way (Dale et al., 2019, 2020). Thus, using the six gears to assess the case studies highlights the contribution each gear, or combination of gears, might have toward enhancing effective stakeholder engagement.

4.1. Lessons learned from applying the six gears

Additionally, these three case studies help illustrate the application of the six gears to effective stakeholder engagement. For example, some stakeholders either disengaged from the process or could not be reached for inclusion in the project process. In the Magic Valley, members of the Indigenous community and an organic farmer stopped attending stakeholder meetings. Although all participants were offered honoraria for their participation, unfortunately these stakeholders declined to divulge why they stopped attending meetings. In Phoenix, the scope of the project did not include representatives of indigenous water rights, likely due to historical mistrust between local Indigenous communities and the university. In the Mexico and Guatemala study, organizers could not debrief the stakeholder communities because of security concerns, COVID, and the termination of funding. This may have impacted the trust developed between researchers and the communities and reduced value. Hence, *accountability* can only be achieved with the long-term commitment of researchers and their funding agencies.

In all case studies, establishing *trust* was the gear that underpinned all other gears. *Listening* can help build trust, and the technique used in the Magic Valley case helped stakeholders understand that researchers valued accurately reflecting what they had to say. *Flexibility* in updating datasets used, giving priority to the indicators of highest importance to stakeholders (*valuing* their expertise also helped build their trust) signaled that researchers valued their opinions, and provided *value* to them as stakeholders. Working with colleagues who had a long history of *trust* with stakeholders from the agricultural areas of Guatemala and

Mexico was essential for effective engagement. Leveraging pre-existing relationships in Phoenix enabled a foundation of rapport that fostered greater *trust* early in the project, and regular updates to project stakeholders enhanced *accountability*.

Consideration needs to be given to how *trust* is built across different levels of power in a given FEW system and across different socio-economic or cultural spectra. A key question to ask is whether stakeholders trust scientists in general, the university or institution conducting the research or leading the project, the individual scientists on the project, or other stakeholders involved in the engagement? To address this concern in the agricultural case studies in this paper, known institutions and scientists from Mexico and from Guatemala were a part of all engagement activities in that case study. In the Magic Valley case study, the research team partnered with the University of Idaho Extension scientists that live and work in the valley and had established relationships with many of the stakeholders. In the Phoenix case study, previous relationship building between the Decision Center for a Desert City and stakeholders before the project began established rapport and trust between researchers and participants. A ubiquitous lesson across all case studies is the need to build on existing trusted relationships because they can take years and a great deal of energy to develop. *Trust* can also be built among stakeholders through active listening and learning to view issues from other stakeholders' perspectives (Frerichs et al., 2017). Working with people always takes time, often requires repeated discussions, and is rarely included in FEWS work plans and funding (Keown et al., 2008). It can be resource intensive when access to participants is difficult or special materials (such as documents prepared in the local language) are required (Kliskey et al., 2021; Gerlak et al., 2023).

Additionally, *diversity* of stakeholders and research teams pose both advantages and risks. Balancing the varied and often divergent interests, backgrounds, and perspectives of different stakeholders and project organizers can be challenging (Haddaway et al., 2017; Hjortso et al., 2005). Divergent backgrounds and perspectives may be hard to navigate during discussions involving conflicting views (Hjortso et al., 2005). Also, some stakeholders may feel that their background and knowledge

is inadequate to contribute to the process (Reed, 2008). *Diversity* of the research team is necessary to understand interactions among the systems and should, at minimum, include a researcher from each of the food, energy, and water systems. Interdisciplinary teams also add to the time needed for the project as jargon and expectations of each discipline need to be negotiated, understood and accommodated. As the values, backgrounds, and knowledge-base of diverse stakeholders and researchers diverge, it might be helpful to engage a skilled facilitator (North et al., 2024) to negotiate the multiple levels and potential differing values of these groups, which can increase project cost. Diverse teams, if managed correctly, increase decision comprehensiveness (Curşeu and Schruiver, 2017) and protect stakeholders from resource depletion (Perrone et al., 2023).

Many researchers are resistant to including stakeholders in decisions about their research projects (Knaggård et al., 2019). As a result, it is sometimes difficult for researchers to sincerely listen to stakeholders. Stakeholders generally have superior knowledge about the practical, or day-to-day functioning of the systems, interactions among systems in their geographic area, and the likely responses of local policy-makers and people. It is important to bring these two ways of knowing and understanding the systems together to identify and implement acceptable and effective solutions. In the Magic Valley case study, a researcher who was seeking to identify indicators was initially skeptical about using stakeholders to do so, expressing a preference for experts, but after engaging with stakeholders, he enthusiastically used the indicators they had chosen. The approach adopted for the agricultural systems in Mexico and Guatemala was to specifically inquire what indicators were important to stakeholders and to always use their preferences. In the Phoenix case study, *listening* involved developing modeling scenarios that were of interest to the engaged stakeholders and integrating those scenarios as policy options in the model, over using researcher-identified policy levers.

The organizational levels at which engagement takes place are important to implementing the six gears, as participation may be best implemented at multiple levels. For example, when considering *diversity*, stakeholders from across numerous governmental levels (e.g., city-level, county-level, state-level) as well as different management levels (e.g., upper management, entry-level positions) should be included in the engagement, for these actors often have differing perspectives and values regarding the integrated FEWS. Stakeholders from different systems, cultural perspectives, and socio-economic groups will likely possess different values and provide different contributions, even from within the same organization. Disparate interests may require unique incentives to encourage participation (Reed, 2008) reflecting the different values of each stakeholder. Providing value to diverse stakeholders requires delicate balancing and honed perception of stakeholder responses. Honoraria are often used as a means to motivate stakeholders, and many stakeholders are also motivated by feeling that their perspectives are being heard on an issue of importance to them and the region in which they live.

Flexibility can also be difficult to implement as it requires changing previously established plans, and there may not be signals to researchers that changes are needed, unless they assess the effectiveness of their engagement as part of the process. *Adaptability* can be challenging because it requires humility in acknowledging that current plans are not working or not optimal. In the Magic Valley case, it took several interactions with stakeholders before researchers removed additional agricultural land from the land-use model and corrected assumptions about water rights. Both *listening*, and *flexibility* incorporating stakeholder input, signal respect for stakeholders and help build *trust* in the process. As planned for the engagement process of the agricultural systems in Mexico and Guatemala, each stakeholder group was asked to identify other individuals or groups who should be contacted, and time was allocated for additional engagement sessions. This *flexible* approach increased the *diversity* of stakeholders in the process and built *trust* for all recommendations that were acted upon. In the Phoenix case, multiple

rounds of stakeholder engagement processes were conducted to develop a visualization of the modeling interface that was sufficiently detailed and also intuitive for non-academic users.

Additionally, we recognize that conflict between the six gears and within the engagement process is inevitable. For example, being *flexible* in a project to include additional components that some stakeholders perceive as important may undermine the *trust* of those stakeholders who disagree. In these delicate situations, it is up to the project team to find additional ways to encourage and sustain engagement without compromising engagement (Reed, 2008). In addition to conflict among the gears, conflict within a project may initially be increased by inclusion of stakeholders with diverse opinions, which requires that participants practice active listening and be empathetic to alternative points of view as they learn to see things from other perspectives (Haddaway et al., 2017; Hjortso et al., 2005). However, as organizers strive to *listen* to stakeholders, build *trust*, practice *accountability* and *flexibility*, and address stakeholder *values* over the course of a project, conflict among project participants has been reduced in our experience.

4.2. Recommendations

Given these lessons, we acknowledge the difficulty of addressing all six gears simultaneously in stakeholder engagements. Many examples in the literature are either too general or describe stakeholder engagement in an ideal situation (Schneider et al., 2021). Therefore, we provide four recommendations based on the lessons learned from the six gears to better prepare research and project teams for more effective engagement.

First, we recommend FEWS project organizers use the six gears as a guide for best-practices in stakeholder engagement of FEWS, while also realizing the difficulties of addressing all six in practice. By integrating the six gears together in planning engagement, considering the challenges of the engagement that may arise in practice, the approach presented here can allow organizers and project managers to design better engagement that balances trade-offs to prioritize the gears most important for the local context and to allow *flexibility* for any of the gears that might be difficult to address.

Second, *accountability* to stakeholders is often a choice made by organizers, for they decide how diverse the group of stakeholders is, how participatory their project process is, how to solicit and include stakeholder perspectives, and what and when to report back. Expectations should be clear to all participants. Organizers can use tools that promote greater *accountability*. For example, they might create “contracts” for stakeholder engagement – such as agreements that lay out expectations for all participants and specify the roles and responsibilities of participants as well as the benefits that they can expect from being active in the process. Such rules could outline the way meetings are conducted – requiring everyone’s participation and civility – or specify how conflicting views will be considered. Creation of a transparent Stakeholder Engagement Plan at the beginning of a project is also a way to ensure that researchers are accountable to stakeholders. By using such tools, organizers can build a more robust version of *accountability* and thus foster stakeholder engagement. However unforeseen events, such as the outbreak of COVID, can and did disrupt planned *accountability* regarding stakeholder engagement in Mexico and Guatemala.

Third, engagement is an aspirational and ongoing process. There is continual commitment to improve implementation of all six gears for stakeholders. Hence, it is important to identify what is the minimum that can be done to include some or all of the gears for a project to be effective or useful. “Doing it right” is not well defined and thus impossible to develop indicators for or formally assess. This paper calls for additional research to identify a useful set of indicators regarding effective stakeholder engagement (Bowen, 2017; Larson and Williams, 2009). One example metric could be relative diversity, meaning the diversity of engaged stakeholders relative to diversity of potential participants. While a checklist of potential indicators would be useful,

organizers need to recognize that the choice of indicators is specific to each context. It will not always be necessary to maximize all of the gears depending on the context, with some gears balancing with others.

Finally, a facilitator or skilled project manager could also be responsible for ensuring all gears are addressed. This responsibility can be achieved by having the implementation team take care to identify key stakeholders and to apply the six gears in their participation in a project. This should include ongoing evaluation of how well the six gears are being applied in a project, including anonymous input from stakeholders about how well the approach reflects their interests and addresses their concerns, and whether they are gaining value by participating. Incorporating this feedback into the project design and implementation is part of the flexibility gear.

5. Conclusions

Stakeholder engagement is important to ensure FEWS projects address important questions about resource management and use in a realistic and helpful manner. It is meant to be part of an ongoing, iterative analysis of shared resources that are cared for and used in a way that is both economically and ecologically sustainable, building on the work of Ostrom and others (Ostrom, 2008). While this article makes some progress toward elucidating effective engagement in FEWS projects, more needs to be done.

Formally testing the six gears in diverse FEW systems would add to the credibility of this approach by suggesting modifications that could improve participation of stakeholders in making decisions about resource use in complex systems. In addition, it would be helpful to document over time how well the six gears can be applied to foster progress toward sustainability. All of the empirical studies cited to date lasted only a few years and do not incorporate effects of long-term changes in social, political, economic, or environmental conditions. In a world of changing climate and disturbance regimes as well as changes in social, political, and economic conditions, such long-term perspectives are essential to evaluate risks and opportunities. Future FEW projects should concentrate on issues related to stakeholder engagement regarding decisions about (1) risk assessment, monitoring, and mitigation; (2) natural resource use and ecosystem service management; and (3) linkages among humans, technologies, and emerging ecosystems (Pahl-Wostl, 2009).

Funding

This research was funded by the National Science Foundation award 1856059 through the EngageINFEWS Research Coordination Network. Case study A (Magic Valley) was funded by the National Science Foundation award 1639524, Case study B (Phoenix) was funded by the National Science Foundation award 1639227, and Case study C/D (Mexico/Guatemala) was funded by the US Agency for International Development contract MTO 069018.

CRediT authorship contribution statement

E.J. Trammell: Conceptualization, Methodology, Investigation, Writing - Original Draft, Writing - Review & Editing, and Supervision. **J. L. Jones-Crank:** Investigation, Writing-Original Draft, Writing-Review & Editing. **P. Williams:** Conceptualization, Methodology, Investigation, Writing - Original Draft, and Writing - review & editing. **M. Babbar-Sebens:** Writing - Original Draft, Writing - Review & Editing, and Visualization. **V.H. Dale:** Writing - Original Draft, Writing - Review & Editing, Visualization and Funding acquisition. **A.M. Marshall:** Investigation, Writing - Original Draft, and Writing - Review & Editing. **A.D. Kliskey:** Conceptualization, Methodology, Investigation, Writing - Original Draft, Writing - Review & Editing, Project administration, and Funding acquisition.

Author statement

We the authors have no competing interests associated with this paper. We did not use AI or AI tools in the generation of this manuscript, and this manuscript is not being considered for publication anywhere else.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Several of the authors are serving as guest editors for a special issue: Williams, P., Dale, V., Marshall, A., and Kliskey, A. Other authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors acknowledge Keith Kline for providing suggestions during the development of the manuscript, and Liz Rousseau for coordinating the EngageINFEWS Theory & Research working group that developed the manuscript.

Data availability

No data was used for the research described in the article.

References

- Asante Boadi, E., He, Z., Bosompem, J., Say, J., Boadi, E.K., 2019. Let the talk count: attributes of stakeholder engagement, trust, perceive environmental protection and CSR, 2158244019825920 Sage Open 9, 2158244019825920.
- Basco-Carrera, L., van Beek, E., Jonoski, A., Benítez-Ávila, C., Guntoro, P.J., 2017. F. Collaborative modelling for informed decision making and inclusive water development. *Water Resour. Manag.* 31, 2611–2625.
- Bielicki, J.M., Beetstra, M.A., Kast, J.B., Wang, Y., Tang, S., 2019. Stakeholder perspectives on sustainability in the food-energy-water nexus. *Front. Environ. Sci.* 7, 7.
- Bisaro, A., Kirk, M., Zdruli, P., Zimmermann, W., 2014. Global drivers setting desertification research priorities: insights from a stakeholder consultation forum. *Land Degrad. Dev.* 25, 5–16.
- Bowen, D.J., et al., 2017. Systematic review of quantitative measures of stakeholder engagement. *Clin. Transl. Sci.* 10, 314–336.
- Bryson, J.M., 2004. What to do when Stakeholders matter. *Public Manag. Rev.* 6, 21–53.
- Cash, D.W., et al., 2003. Knowledge systems for sustainable development. *Proc. Natl. Acad. Sci.* 100, 8086–8091.
- Chachine, I.E., 2022. Values-Based Participatory Action Research in Development Ethics. In: Espedal, G., Jelstad Løvaas, B., Sirris, S., Wæraas, A. (Eds.), in *Researching Values: Methodological Approaches for Understanding Values Work in Organisations and Leadership*. Springer International Publishing, Cham, pp. 279–297. https://doi.org/10.1007/978-3-030-90769-3_16.
- Chief, K., Meadow, A., Whyte, K., 2016. Engaging Southwestern tribes in sustainable water resources topics and management. *Water* 8, 350.
- Williams, P., et al., 2025. Rethinking stakeholder engagement: a multidimensional framework inspired by meta-analysis of food, energy, and water research. In review *Nature Sustainability*.
- Chief, K., Daigle, J.J., Lynn, K. & Whyte, K.P. Indigenous experiences in the U.S. with climate change and environmental stewardship in the Anthropocene. In: Sample, V. Alaric; Bixler, R. Patrick, eds. *Forest conservation and management in the Anthropocene: Conference proceedings*. Proceedings. RMRS-P-71. Fort Collins, CO: US Department of Agriculture, Forest Service. Rocky Mountain Research Station. p. 161-176. 71, 161–176 (2014).
- Coates, T., Tapsell, S., 2019. Planning for an uncertain future: the challenges of a locally based collaborative approach to coastal development decisions. *Environ. Sci. Policy* 101, 24–31.
- Cosens, B., et al., 2021. Governing complexity: integrating science, governance, and law to manage accelerating change in the globalized commons. *Proc. Natl. Acad. Sci.* 118, e2102798118.
- Creed, R., Baily, B., Potts, J., Bray, M., Austin, R., 2018. Moving towards sustainable coasts: a critical evaluation of a stakeholder engagement group in successfully delivering the mechanism of adaptive management. *Mar. Policy* 90, 184–193.
- Cronan, D., Trammell, E.J., Kliskey, A. (Anaru), 2022. Images to evoke decision-making: building compelling representations for stakeholder-driven futures. *Sustainability* 14, 2980.

- Curşeu, P.L., Schrujver, S.G., 2017. Stakeholder diversity and the comprehensiveness of sustainability decisions: the role of collaboration and conflict. *Curr. Opin. Environ. Sustain.* 28, 114–120.
- Daher, B., Mohtar, R.H., Lee, S.-H., Assi, A., 2017. Modeling the water-energy-food nexus. in *Water-Energy-Food Nexus*. American Geophysical Union (AGU), pp. 55–66. <https://doi.org/10.1002/9781119243175.ch6>.
- Dale, V.H., et al., 2020. Towards more sustainable agricultural landscapes: lessons from Northwestern Mexico and the Western Highlands of Guatemala. *Futures* 124, 102647.
- Dale, V.H., Kline, K.L., Parish, E.S., Eichler, S.E., 2019. Engaging stakeholders to assess landscape sustainability. *Landsc. Ecol.* 34, 1199–1218.
- Eichler, S.E., Kline, K.L., Ortiz-Monasterio, I., Lopez-Ridaura, S., Dale, V.H., 2020. Rapid appraisal using landscape sustainability indicators for Yaqui Valley, Mexico. *Environ. Sustain. Indic.* 6, 100029.
- Fennell, L.E., 2011. Ostrom's Law: Property rights in the commons. *International Journal of the Commons* 5, 9–27.
- Ferguson, L., Chan, S., Santelmann, M.V., 2018. Transdisciplinary research in water sustainability: what's in it for an engaged researcher-stakeholder community? *Water Altern.* 11, 18.
- Ferguson, L., Chan, S., Santelmann, M., Tilt, B., 2017. Exploring participant motivations and expectations in a researcher-stakeholder engagement process: Willamette Water 2100. *Landsc. Urban Plan.* 157, 447–456.
- Frerichs, L., et al., 2017. Stakeholder perspectives on creating and maintaining trust in community-academic research partnerships. *Health Educ. Behav.* 44, 182–191.
- Gerlak, A.K., et al., 2023. Stakeholder engagement in the co-production of knowledge for environmental decision-making. *World Dev.* 170, 106336.
- Green, J.M.H., et al., 2017. Research priorities for managing the impacts and dependencies of business upon food, energy, water and the environment. *Sustain Sci.* 12, 319–331.
- Grove, M., et al., 2024. Forging just ecologies: 25 years of urban long-term ecological research collaboration. *Ambio* 53, 826–844.
- Guan, X., Mascaro, G., Sampson, D., Maciejewski, R., 2020. A metropolitan scale water management analysis of the food-energy-water nexus. *Sci. Total Environ.* 701, 134478.
- Gupta, A.D., 2017. Water-Energy-Food (WEF) Nexus and Sustainable Development. in *Water-Energy-Food Nexus*. American Geophysical Union (AGU), pp. 221–241. <https://doi.org/10.1002/9781119243175.ch19>.
- Guston, D.H., 1999. Stabilizing the boundary between US politics and science: the rôle of the office of technology transfer as a boundary organization. *Soc. Stud. Sci.* 29, 87–111.
- Guston, D.H., 2001. Boundary organizations in environmental policy and science: an introduction. *Sci. Technol. Hum. Values* 26, 399–408.
- Haddaway, N.R., et al., 2017. A framework for stakeholder engagement during systematic reviews and maps in environmental management. *Environ. Evid.* 6, 11.
- Hampel, C.E., Tracey, P., Weber, K., 2020. The art of the pivot: how new ventures manage identification relationships with stakeholders as they change direction. *AMJ* 63, 440–471.
- Hargrove, W.L., Heyman, J.M., 2020. A comprehensive process for stakeholder identification and engagement in addressing wicked water resources problems. *Land* 9, 119.
- Harris, F., Lyon, F., 2013. Transdisciplinary environmental research: building trust across professional cultures. *Environ. Sci. Policy* 31, 109–119.
- Hjortso, C.N., Christensen, S.M., Tarp, P., 2005. Rapid stakeholder and conflict assessment for natural resource management using cognitive mapping: the case of Damdoi Forest Enterprise, Vietnam. *Agric. Hum. Values* 22, 149–167.
- Holmatov, B., Lautze, J., Uhlenbrook, S., 2023. The nexus across water, energy and food (WEF): learning from research, building on evidence, strengthening practice. *Nat. Resour. Forum* 47, 817–841.
- Hoolohan, C., et al., 2018. Engaging stakeholders in research to address water-energy-food (WEF) nexus challenges. *Sustain Sci.* 13, 1415–1426.
- Jones, J.L., White, D.D., 2022. Understanding barriers to collaborative governance for the food-energy-water nexus: the case of Phoenix, Arizona. *Environ. Sci. Policy* 127, 111–119.
- Keown, K., Van Eerd, D., Irvin, E., 2008. Stakeholder engagement opportunities in systematic reviews: knowledge transfer for policy and practice. *J. Contin. Educ. Health Prof.* 28, 67–72.
- Kirtley, J., O'Mahony, S., 2020. What is a pivot? Explaining when and how entrepreneurial firms decide to make strategic change and pivot. *Strat. Mgmt. J.*, smj.3131 <https://doi.org/10.1002/smj.3131>.
- Kline, K.L., Ramirez, L.F., Sum, C., Lopez-Ridaura, S., Dale, V.H., 2020. Enhance indigenous agricultural systems to reduce migration. *Nat. Sustain.* 3, 74–76.
- Kliskey, A., et al., 2021. Thinking big and thinking small: a conceptual framework for best practices in community and stakeholder engagement in food, energy, and water systems. *Sustainability* 13, 2160.
- Kliskey, A., "Anaru", et al., 2023. Building trust, building futures: knowledge co-production as relationship, design, and process in transdisciplinary science. *Front. Environ. Sci.* 11.
- Knaggård, Å., Slunge, D., Ekblom, A., Göthberg, M., Sahlin, U., 2019. Researchers' approaches to stakeholders: Interaction or transfer of knowledge? *Environ. Sci. Policy* 97, 25–35.
- Krupa, M., Cenek, M., Powell, J., Trammell, E.J., 2018. Mapping the stakeholders: using social network analysis to increase the legitimacy and transparency of participatory scenario planning. *Soc. Nat. Resour.* 31, 136–141.
- Landriani, L., Agrifoglio, R., Metallo, C., Lepore, L., 2022. The role of knowledge in water service coproduction and policy implications. *Uti. Policy* 79, 101439.
- Larson, S., Williams, 2009. Monitoring the success of stakeholder engagement: Literature review. In Measham, T., Brake, L.(Ed.), in *People, communities and economies of the Lake Eyre Basin*, DKCRC Research Report 45, Desert Knowledge Cooperative. Research Centre, Alice Springs, pp. 251–298.
- Lewis, C.W., Lewis, C.W., Gilman, S., Gilman, S.C., 2012. The ethics challenge in public service: A problem-solving guide. Jossey-Bass, San Francisco, CA.
- Macnamara, J., 2020. Public sector communication measurement and evaluation. In: Luoma-aho, V., Canel, M. (Eds.), in *The Handbook of Public Sector Communication*. Wiley, pp. 361–365. <https://doi.org/10.1002/9781119263203.part5>.
- McGreevy, S.R., et al., 2022. Sustainable agrifood systems for a post-growth world. *Nat. Sustain* 5, 1011–1017.
- Miller, C., 2001. Hybrid management: boundary organizations, science policy, and environmental governance in the climate regime. *Sci. Technol. Hum. Values* 26, 478–500.
- Mitchell, R.K., Agle, B.R., Wood, D.J., 1997. Toward a theory of stakeholder identification and salience: defining the principle of who and what really counts. *Acad. Manag. Rev.* 22, 853–886.
- Mounir, A., Mascaro, G., White, D.D., 2019. A metropolitan scale analysis of the impacts of future electricity mix alternatives on the water-energy nexus. *Appl. Energy* 256, 113870.
- Norström, A.V., et al., 2020. Principles for knowledge co-production in sustainability research. *Nat. Sustain* 3, 182–190.
- North, E.W., et al., 2024. Two applications of the Consensus Solutions process with collaborative modeling for management of a contentious oyster fishery. *Front. Mar. Sci.* 11.
- Nutt, P.C., Backoff, R.W., 1992. Strategic management of public and third sector organizations: A handbook for leaders. Jossey-Bass, San Francisco, CA.
- Oates, J., Dodds, L.A., 2017. An approach for effective stakeholder engagement as an essential component of the ecosystem approach. *ICES J. Mar. Sci.* 74, 391–397.
- Ojha, H., et al., 2022. Transforming environmental governance: critical action intellectuals and their praxis in the field. *Sustain Sci.* 17, 621–635.
- Ostrom, E., 2008. Institutions and the environment. *Econ. Aff.* 28, 24–31.
- Pahl-Wostl, C., 2009. A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Glob. Environ. Change* 19, 354–365.
- Parker, J., Crona, B., 2012. On being all things to all people: boundary organizations and the contemporary research university. *Soc. Stud. Sci.* 42, 262–289.
- Perrone, D., et al., 2023. Stakeholder integration predicts better outcomes from groundwater sustainability policy. *Nat. Commun.* 14, 3793.
- Polk, M., 2015. Transdisciplinary co-production: designing and testing a transdisciplinary research framework for societal problem solving. *Futures* 65, 110–122.
- Reed, M.S., 2008. Stakeholder participation for environmental management: a literature review. *Biol. Conserv.* 141, 2417–2431.
- Rogers, E.M., 2003. Diffusion of Innovations, 5th Edition. Free Press, New York London Toronto Sydney.
- Schneider, F., et al., 2021. Co-production of knowledge and sustainability transformations: a strategic compass for global research networks. *Curr. Opin. Environ. Sustain.* 49, 127–142.
- Scholes, E., Clutterbuck, D., 1998. Communication with stakeholders: an integrated approach. *Long. Range Plan.* 31, 227–238.
- Shinde, V.R., 2017. Water-energy-food nexus: Selected tools and models in practice. In: Abdul Salam, P., Shrestha, S., Pandey, V.P., Anal, A. (Eds.), in *Water-energy-food nexus: principles and practices*. Wiley; American Geophysical Union, Hoboken, NJ: Washington, D.C.
- Sterling, E.J., et al., 2017. Assessing the evidence for stakeholder engagement in biodiversity conservation. *Biol. Conserv.* 209, 159–171.
- Sušnik, J., et al., 2018. Multi-stakeholder development of a serious game to explore the water-energy-food-land-climate nexus: the SIM4NEXUS Approach. *Water* 10, 139.
- Trabucco, A., et al., 2018. Water-food-energy nexus under climate change in Sardinia. *MDPI Proceed.* 2, 609.
- Trammell, J., Krupa, M., Williams, P., Kliskey, A., 2021. Using comprehensive scenarios to identify social-ecological threats to salmon in the kenai river watershed, Alaska. *Sustainability* 13, 5490.
- Wahl, D., Ness, B., Wamsler, C., 2021. Implementing the urban food-water-energy nexus through urban laboratories: a systematic literature review. *Sustain Sci.* 16, 663–676.
- Weitz, N., Strambo, C., Kemp-Benedict, E., Nilsson, M., 2017. Closing the governance gaps in the water-energy-food nexus: insights from integrative governance. *Glob. Environ. Change* 45, 165–173.
- White, D.D., Jones, J.L., Maciejewski, R., Aggarwal, R., Mascaro, G., 2017. Stakeholder analysis for the food-energy-water nexus in phoenix, Arizona: implications for nexus governance. *Sustainability* 9, 2204.
- Whyte, K., 2014. A Concern About Shifting Interactions between Indigenous and Non-Indigenous Parties in US Climate Adaptation Contexts. SSRN Scholarly Paper at (<https://papers.ssrn.com/abstract=2439236>) 2014.
- Williams, P., et al., 2023. Constructing futures, enhancing solutions: Stakeholder-driven scenario development and system modeling for climate-change challenges. *Front. Environ. Sci.* 11.