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Alignment of stakeholder and scientist understandings and expectations in a participatory modeling project

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ABSTRACT

Participatory and transdisciplinary approaches to research, modeling, and community engagement have become increasingly popular. Yet even when diverse stakeholders and scientists are brought together, it is not clear they share the same understandings of the goals of the participatory process or how stakeholder knowledge will be utilized. Our research documents the degree of alignment in initial expectations between stakeholders and scientists in a large participatory modeling project designed to determine how changes in global trade will impact food-energy-water systems in the eastern Corn Belt/Great Lakes region of the USA. We combined qualitative semi-structured interviews and a quantitative online survey to measure how consistent the expectations and understandings were between scientists and stakeholder advisors at an early stage of the project.

We found that people participated for many personal and professional reasons. All participants were seeking an opportunity to engage in stimulating and enlightening discussions. Although the project was conceived using a co-production model, most participants initially assumed that stakeholder roles would be consultative, where stakeholder input would be used to inform decisions by scientists about scenario and model choices. Although everyone valued scientific and societal outcomes, scientists prioritized academic outputs more highly than stakeholders, who pointed to the use and impact of the work outside of academia as the most important outcome. Overall, we identified areas of both alignment and misalignment in initial understandings and expectations among scientists and stakeholders that should be addressed through an adaptive process to maximize the likelihood of project success.

1. Introduction

Over the last decade, there has been a growing interest in the complex dynamics of coupled food-energy-water systems (FEWS), which are collectively responsible for shaping much of the social, economic, and environmental sustainability footprint of human society (Hoff, 2011; Simpson and Jewitt, 2019). In recent years, academics have developed a growing number of integrated datasets and models designed to shed light on dynamics of the FEWS Nexus (Endo et al., 2017). Despite this flurry of activity, societal action to use this information to counteract these problems has been slow, suggesting that there is a serious gap between the knowledge produced by researchers and the utilization of this knowledge by decision-makers (Lemos et al., 2012; Yung et al., 2019).

To narrow this gap, the FEWS modeling community has experimented with a wide variety of approaches and methods to develop and disseminate their work (Howarth and Monasterolo, 2017; Proctor et al., 2021). In particular, a number of authors have called for more participatory approaches that can (in theory) better reflect stakeholder experiences and perspectives and generate opportunities for trust building and social learning that should increase decision-makers' understanding and use of modeling results (González-Rosell et al., 2020; Klenk and Meehan, 2017; Thompson et al., 2017; Mach et al., 2020; Voinov and Bousquet, 2010).

The transdisciplinary research (TDR) approach represents one of the highest degrees of integration of expert and practitioner knowledge (Thompson et al., 2017; Pohl et al., 2021). This way of doing research has also been referred to as post-normal science, Mode-2 knowledge production, or knowledge co-production and simultaneously aims to solve societal problems while expanding scientific understanding through knowledge integration and collaboration between academic and non-academic actors (Hessels and Van Lente, 2008; Funtowicz and

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Ravetz, 1993; Gibbons et al., 1994; Hirsch Hadorn et al., 2006, 2008; Lux et al., 2019). One assumption of TDR approaches is that non-scientific actors and stakeholders hold valid and complementary knowledge and expertise about the FEWS nexus that is required to solve complex wicked problems (Bracken et al., 2015; Chilisa, 2017; Polk, 2015).

Most advocates for TDR approaches argue that they can provide information that is more relevant, credible, legitimate, and effective than conventional disciplinary and expert-led research and modeling (Belcher et al., 2016). In addition, unlike traditional academic work that generates scientific products primarily accessed by scholars (e.g., academic papers and conference presentations), TDR approaches are expected to generate outputs that can have more direct effects on societal decision-making. Wiek et al. (2014) provide a framework that categories these societal impacts into four types: (a) usable products, (b) enhanced decision-maker capacity, (c) expanded networks or ties among key actors across sectors, and (d) structural changes and actions (like changes in law and policy).

The design and implementation of TDR processes can vary widely, and factors like participant motivation, perceived importance of the project, and opportunities for in-depth exchanges between scientists and stakeholders can influence how knowledge outputs are developed and whether they are likely to impact real-world decisions (Barreteau et al., 2010; Hansson and Polk, 2018). Assessments of TDR work often explore impacts on project participants after a project is done (e.g., changes in understanding, knowledge, and capacity for both participating scientists and stakeholders) as well as on decisions and actions in the 'real world' beyond the project itself that are required to produce improved societal sustainability and resilience (Lux et al., 2019; Schmidt and Pröpper, 2017; Zscheischler et al., 2018).

Despite the importance given to the involvement of practitioners from non-academic contexts in TDR approaches, ontological and epistemological boundaries and gaps between researchers and other societal actors can make the translation of knowledge to action a real challenge (Hirsch Hadorn et al., 2006; Klein, 2015; Klenk and Meehan, 2017). Scientists can be challenged to yield control over research design and model specification to practitioners who often lack formal scientific training (Siebenhüner, 2018). Most scientists also share a 'realist' epistemological worldview that can limit their ability to appreciate and incorporate experiences, knowledge, and perceptions of stakeholders that are derived from non-scientific sources (Chilisa, 2017; Klenk and Meehan, 2017). Meanwhile, stakeholders often perceive academic modeling research as abstracted from the lived reality of societal actors and less relevant or practical for dealing with problems in the real world (Bracken et al., 2015)). As a result, it is not safe to assume that understandings of the purpose and likely outcomes of a TDR process between scientist and stakeholder participants are well aligned (Barreteau et al., 2010; Roux et al., 2017; Guimarães et al., 2019; Thompson et al., 2017).

Some TDR efforts leave space for the approach to be adapted and shaped by participants during the course of a project (Polk, 2015). As a result, it can be helpful to take stock of the relative perceptions and expectations of scientists and non-scientist partners at the beginning of the TDR process in order to identify whether participants share the same assumptions about the purpose, goals, and expected outcomes associated with the collaborative effort (Mach et al., 2020). Also, the broad-scale and scope of TDR projects mean that there are often many actors involved who are likely to come from a wide range of backgrounds with varying experiences, worldviews, and perspectives about collaborative research approaches (Hilger et al., 2021; Hirsch Hadorn et al., 2006; Hirsch Hadorn et al., 2006). These factors might impact the views and perceptions of the participants with respect to the importance of involving stakeholders, the appropriate timing of involvement, and the relevance of project objectives and outcomes (Hirsch Hadorn et al., 2006; Roux et al., 2017; Guimarães et al., 2019).

Only a few studies have assessed the mindsets, expectations, and tensions among scientists and stakeholders at the outset of a TDR project. In one recent example, Thompson et al. (2017) found a high degree of convergence among participants in their understanding of the goals and agreement about the best approaches to co-create knowledge. Still, they identified several potential areas of conflict and tension – most created by the institutional reward systems and structures surrounding participating scientists and stakeholders. Frescoln and Arbuckle (2015) surveyed scientists, extension personnel, and advisory board members at the outset and midpoint of a 5-year TDR project and found that collaborative behaviors and attitudes generally increased over time. Binder et al. (2020) surveyed practitioners and researchers involved in a national collaborative research project and documented how different expectations and understandings of participants shaped the perceived relevance and importance of the project. Woltersdorf et al. (2019) present a case study focused on the early phases of a transdisciplinary project that highlights the value of investing time and resources in facilitating engagement and open discussions between scientists and stakeholders to define problems, formulate objectives, and design a TDR approach.

This study uses a mixed-methods approach to assess the degree of alignment in priorities and expectations among scientist and stakeholder advisors involved in a participatory modeling project designed to simulate the implications of deglobalization for integrated Food-Energy-Water systems in the eastern Corn Belt, USA. Our aim was to examine the initial perceptions of scientists and stakeholders related to their (1) motivations to be involved in the project, (2) understanding of the role played by stakeholders, (3) perceived importance of different project outcomes, and (4) anticipated likelihood of achieving these outcomes.

1.1. The DR-FEWS project

We explore these questions using data collected from the Dynamic Regional Food, Energy, Water Systems (DR-FEWS) project, a large TDR project funded by the U.S. National Science Foundation (INFEWS/TI NSF Project #1739909). This project started in 2018 and uses a participatory modeling approach to develop scenarios and a coupled systems model to assess the potential impact of 'deglobalization' – defined as a shift away from long term trends towards increased global interdependence and flows of capital, goods, and labor – on the Food, Water, and Energy Systems (FEWS) on a five-state region. This region is situated at the intersection of the Great Lakes and the Corn Belt, and includes the states of Illinois, Indiana, Michigan, Ohio, and Wisconsin (Bielicki et al., 2018).

To determine the extent to which these impacts can be predicted, the project brought together scientists from different disciplines and key stakeholders that work at the local, state, and regional scale in the agricultural, food, water, and energy sectors. The research team included professors, postdoctoral researchers, and graduate students with diverse and complementary expertise in dynamic stochastic economic modeling, water quality and ecosystem service modeling, energy infrastructure modeling, life cycle and other sustainability assessment methods, farmer decision making, land-use change modeling, and participatory processes.

We created a set of participatory stakeholder advisory groups to guide the development and application of our coupled economic-environmental systems model (the 'DR-FEWS' model). These included a Regional Advisory Council (RAC) and two Participatory Modeling Advisory Teams (PMATs). Our plan was to use stakeholder input to improve the accuracy of the models, refine specific elements of future scenarios that will be tested with the model, and ultimately increase the utility and legitimacy of the project outcomes.

The initial RAC had 20 members who represent a mix of 10 representative local, state, and regional governance actors who have responsibilities for managing food, energy, and water resources in the region, and 10 leaders from key state or regional stakeholder organizations representing agriculture, regional food systems, consumer, and environmental interests (Bielicki et al., 2019). The two PMATs initially included 6 and 7 members, respectively. The first PMAT included farmers and farm organization representatives and the second PMAT included experts from the energy, agribusiness, environmental, and regional planning agencies. The RAC and PMAT members had not been involved in the drafting of the original proposal, but were recruited by the science team to be contribute to the participatory modeling work, making our project more of a top-down than bottom-up version of stakeholder engagement (Reed et al., 2018).

2. Methods

A mixed-methods approach (Creswell and Creswell, 2017) was adopted for this study, which started with qualitative semi-structured interviews, followed by the implementation of a quantitative online survey with project team members and stakeholder advisors. In both cases, information was collected from scientists and stakeholders to assess the degree of alignment in priorities and expectations among them related to the DR-FEWS project. Both instruments were implemented within the first 8 months of initiating the project.

For the present analysis, we categorized participants into two groups: 'scientists' or researchers who have different positions in academia such as professors, postdoctoral researchers, and graduate students; and 'stakeholders' who represent government agencies, private sector industries, and civil society organizations working on agriculture/food, energy, and water topics. The stakeholders were all members of the RAC and PMATs advisory groups.

2.1. Semi-structured interviews

To capture detailed information about participant motivations and expectations, we first conducted 38 semi-structured interviews with 16 scientists (7 female and 9 male) and 22 stakeholders (7 female and 15 male). This sample comprised all but 2 of the original science team members and almost 75% of the RAC and PMAT members. The interview consisted of 25 open-ended questions and covered five topics related to (1) understandings of the roles of participants in the project; (2) interpretation or knowledge of key project concepts; (3) sense of the importance of different project goals and outcomes; (4) perceptions about the purpose and value of stakeholder input; and (5) feedback on project management. Systematic probes, adaptive lines of questioning, a promise of strict confidentiality, and assurances that there were no right or wrong answers were strategies used to ensure the collection of in-depth and unbiased information from the participants (Berg, 2009). Each interview lasted around 30–40 min. All the interviews were recorded and transcribed with the permission of the participants.

We employed a systematic and iterative thematic analysis approach to process the interview transcripts to identify and validate emergent themes and patterns in the data (Braun and Clarke, 2006). Specifically, we used NVivo software to classify answers to each of the interview questions into a distinctive set of codes or themes. Because the interview instrument had questions focused on similar topics, we focused our analysis on classifying the answers within each topical domain into a set of coherent categories, then noted which themes were more frequently mentioned by scientists and stakeholders. To ensure validity and reliability, the interviews were coded by two authors, and then reviewed and refined in an iterative fashion until agreement was reached on the best set of categories and classification criteria for assigning specific answers to each category (Potter and Levine-Donnerstein, 1999).

2.2. Online survey

Following each interview, a link to an online survey was distributed to the participants through e-mail invitations. The questionnaire was designed and implemented on a Qualtrics platform. The survey included questions about the respondent's experience and expertise across the FEWS nexus sectors, interactions with the public and key stakeholders, and a number of closed-answer format questions that probed the same topics as those included in the semi-structured interviews (e.g., ranking of the importance of different project outcomes, rating the likelihood that different outcomes would occur, and assessment of the participatory process and understanding about the role of stakeholders in model development). A total of 34 project participants (19 stakeholders and 15 scientists) completed the online survey (89%). Data were transferred to SPSS software for descriptive statistical analysis. Below we compare answer patterns between members of the research team ('scientists') and members of the advisory boards ('stakeholders').

3. Results

Our findings center on four critical themes that allowed us to compare the alignment of scientist and stakeholder participants understandings and expectations: (1) personal motivation for participation, (2) the role of stakeholder participants, (3) perceived importance of different project outcomes, and (4) perceived likelihood of achieving outcomes.

3.1. Personal motivations for participation

During the interviews, respondents were asked to explain why they got involved in this type of TDR project, what they found to be the most interesting part of the project, and what they personally expect to gain from the collaboration.

Most scientists highlighted the opportunity to work on an interdisciplinary team. One said "*I really enjoy interdisciplinary projects. I think they can better answer more complicated questions, and I just enjoy learning more about different fields instead of learning more about my field.*" *(SCI-2)*[1] Another pointed at "*The team science portion. For it's best parts and it's worst parts. Its always good for disciplines, especially when you're thinking about something like your food, energy, water system broadly…(to) study and talk to one another.*" *(SCI-10)* Three of the 22 stakeholders also listed a desire to be part of an interdisciplinary project. One called out.

> "the value of having a lot of different disciplines in the same room, thinking about the same question. I think one of humanity's weak points is being able to take a truly systems approach to an issue, and that's one of the reasons I said yes to participating." (SH-34)

Others highlighted the opportunities to meet and collaborate with non-academic stakeholders. Three of the 16 scientists mentioned the participatory approach as an attractive feature, though all three commented on the challenges associated with building models with stakeholders. In one's words,

> "I think the most interesting aspect is also some of the most challenging aspects of the project. It's bringing in the perspective of the stakeholders that we're engaged with through the RAC and through the PMATs. And meshing that with what ultimately is still a highly stylized model of the regional economy and of land use change in the Great Lakes region and I think that if we can make progress on that, that will be incredibly novel and also useful." (SCI-6)

About a third of stakeholders mentioned a desire to engage and hear from 'experts', and they included both academics and expert practitioners in that category. One said "*the conversation among experts is the part of the project that is most interesting to me,*" *(SH-25)* while another emphasized "*sitting around the table with some very, very smart thinkers that I wouldn't otherwise have some interaction with.*" *(SH-35)* Another stakeholder clarified that "*where you had various stake holders in the room*

[1] Extended quotes from scientists and stakeholders are denoted using either SCI or SH in parentheses, respectively.

was the most interesting part. To hear other people's perspective, and so forth, was important." *(SH-22).*

Stakeholders often emphasized a desire to improve their own personal understanding of the dynamics of the regional FEW system and the potential impacts of globalization as a key motivation. These respondents emphasized the value of the project generating new knowledge that could inform their ability to make good decisions. One noted that "*to me it's interesting to see what studies come up with what. It's just interesting. It's a learning process for me*" *(SH-18)* while another mentioned that.

> "I'm definitely interested in how these predictive models may help somebody like myself who's trying to implement programs and landscape, prioritize and be a little bit strategic about how we do that implementation and what projects to fund and how perhaps to better track those over time." (SH-31)

> A third elaborated:

> ".to think about how all of these very large systems, and not just systems in the U.S., but global systems you know, work together to have an impact on something that I care deeply about at a very local level…being able to think more about and learn more about how those national and global systems are interacting to have an impact on the much more narrow set of issues that I work on related to Great Lakes water quality and quantity."(SH-38)

These qualitative findings were echoed in the online survey results (Fig. 1). Nearly all participants felt that they would gain a better understanding of the impacts of deglobalization on the region. While most respondents were optimistic about the value of engaging in participatory modeling, scientists were somewhat more confident than stakeholders that their time would be well spent. A much larger share of scientists expected to personally make a significant contribution to the team's modeling work (86% vs. 55% of. stakeholder advisors), and stakeholders were much less likely to feel that their work on the project would directly improve their ability to solve problems in their work.

3.2. The role of stakeholder participants

Due to complexity of the FEWS nexus, scientists are often encouraged to go beyond traditional scientific approaches and incorporate non-scientific actors' views and knowledge through stakeholder participation (Mielke et al., 2016). Indeed, the original proposal for the DR-FEWS project highlighted the value of a participatory approach to the development of scenarios and models. Our online survey and interviews provide insights into the extent to which different participants shared a common understanding about the purpose and expectations of the 'participatory modeling' component of the project. Specifically, in the survey, we asked whether they agreed that the PMAT and RAC would provide input that would significantly alter the coupled systems models we develop (Table 1). Results suggest that stakeholders had relatively high expectations that their contributions would impact the models (over 60% agreed, and a third were not sure). By contrast, scientists were split – with about half agreeing or strongly agreeing with the statement, but a significant minority (37%) disagreeing.

Interview participants were also asked to reflect on the most valuable contributions and expected roles of the stakeholder advisors on the project. Their answers fell into three overlapping themes: widening perspectives on the team, improving the science and modeling, and increasing the impacts of the project on society.

In the first instance, both scientists and stakeholders frequently talked about how the stakeholder advisors would "*ground the project in*

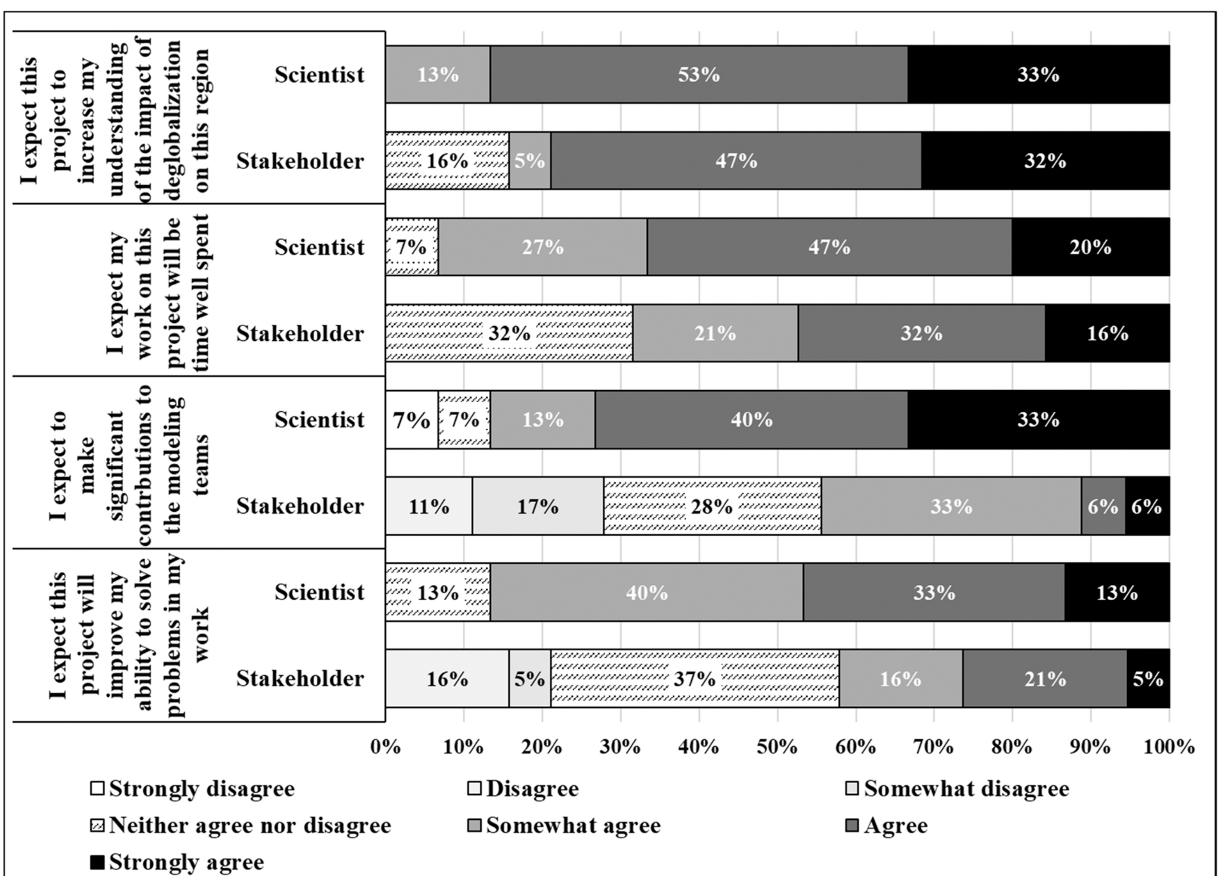

Fig. 1. Expectations and preferences for involvement in the project.

Table 1
Percent of scientists and stakeholder advisors in agreement with statement about impact of stakeholder advisors on coupled systems models.

	I expect the input of members of the PMAT and RAC to significantly alter the models developed by university scientists on this project.	
	Scientists	Stakeholders
Disagree or Strongly Disagree	16.7	5.6
Somewhat disagree	20.0	0.0
Neither agree nor disagree	16.7	33.3
Somewhat agree	0.0	27.8
Agree or strongly agree	46.7	33.4

reality." *(SCI-4)* Over half of the scientists and nearly all of the stakeholders gave examples, as represented by the following selected quotes:

> "Hearing their perspective, and sometimes we think these things are way more important than they do. That's, knowing how they see the world differently from us and how they're experiencing the world that we're trying to study, they're in it and experiencing it. Hearing that perspective is very valuable." (SCI-6)

> "Real world experience. I know my land, my philosophy and the way I work, so my perspective is what I bring as opposed to a general perspective. I bring a little different perspective." (SH-19)

> "Sort of real-world lived experience about what we see happening in the wider world and the marketplace, that may or may not be on the radar for people who are doing more basic research in a university setting." (SH-34)

For most scientists on the team, this broadening of perspective was associated with opportunities to improve the science or modeling work. Specific examples included providing feedback on the design of a farmer survey, ground-truthing assumptions in the models, identifying realistic or interesting scenarios to run on the models, and being a reality check for whether or not the model predictions make sense. Some exemplar quotes include:

> "So I think their role is to, again, to really ground the researchers in reality and making assumptions for models. Asking, or challenging the researchers to clearly explain results. It could help potentially direct questions that we want to ask the models." (SCI-7)

> "The thing is about stakeholders is they're revealing to you what their decision-making process is. That helps with the construction of the model, the successful ness of the outputs and everything." (SCI-10)

> "We want to make sure those scenarios are interesting questions or interesting dilemmas that these stakeholders have, because those are going to be the interesting scenarios or dilemmas for society, I guess. So that would help keep things relevant." (SCI-2)

> "Improving the model and improving our research, how to package it, and how to talk about it… I think they play the role of advisor. They play the role of bringing knowledge and experience to the project. That's important. They do oversight of us, so they help tell us when we're maybe not on the right track." (SCI-12)

Stakeholders also discussed ways in which they felt they could improve the scientific research or modeling work, but were less likely to have identified specific or concrete examples of what that might look like (understanding that it was still early in the project when they were asked).

> "Just being a very open communication and honest and saying, 'That's crazy.' I think probably whenever the team that's running it identifies any challenges or problems or questions they've just got to pull the group together and say, 'Hey. We're experiencing this and we need your feedback, help and feel free to do that." (SH-17)

> "I think everybody can (contribute) depending on what hat they wear and what their realm of experience is brings important questions and being able to question the assumptions and looking at the aspects of what is going to be modeled and what isn't going to be modeled." (SH-33)

> "Stakeholders and advisors have often times much of a greater appreciation of constraints than do academics. And I think they can help academics understand that they have an incomplete model…" (SH-27)

In addition to broadening the internal discussions and improving the science and modeling work, a number of the scientists and stakeholders in our interviews felt that engaging stakeholders in a participatory modeling project would serve to increase the chances the project would have an impact on broader society. This would be partly because their input would lead to more relevant and impactful outputs. One stakeholder noted that they would "*make sure that the results of the project can answer some of those pressing questions and issues that decision-makers are looking at." (SH-26)* Another indicated the hope that stakeholder input "*in the long term can provide a more accurate product or a more acceptable product to kind of a broader audience." (SH-36)* A scientist emphasized that "*I think it's also extremely helpful to know what they need and what products out of this project would be useful to them. We need to know what they need and be able to produce that in a format that is usable for them." (SCI-4)* In addition, scientists, in particular, felt that the stakeholder advisors could serve as ambassadors for the project and bring results to a wider audience. In the words of one scientist, stakeholders could:

> "Help bring out the results to the larger constituents, if they're able to understand the results, and the processes, and they're okay with it. They can help spread that message, and even help formulate, I guess, the overall project report if they wanted to have input into it. … also help develop the messages and spread the word to decision makers and others throughout the region who will potentially use the results of this research down the road." (SCI-7)

3.3. Perceived importance of different project outcomes

We also used the results of the online survey and in-depth qualitative interviews to assess whether the scientists and stakeholders on the project held similar perspectives about the importance of various outcomes associated with our TDR project. In the online survey, each respondent was presented with a list of possible outcomes from the DRFEWS project and asked to rate them based on "how important each outcome is to the success of our project. In other words – what would be the most important evidence that we have succeeded?" Similarly, in the semi-structured interviews, we asked respondents three interrelated questions:

- From what you've heard or read, what do you think are the most important objectives of the DR FEWS project?
- If we succeed, what do you think should be the primary outcomes of our project?
- What would be the best metric or measure of whether the project was successful?

Based on their quantitative and qualitative answers, we clustered examples of potential outcomes into two broad categories: (a) impacts on science and academic knowledge, and (b) impacts on society. Within each category, we identified a number of key themes or topics.

For three key scientific outcomes listed in the online survey, the scientists on the team were much more likely to rate them as important than our stakeholder advisors (Fig. 2). For example, 87%of scientists felt

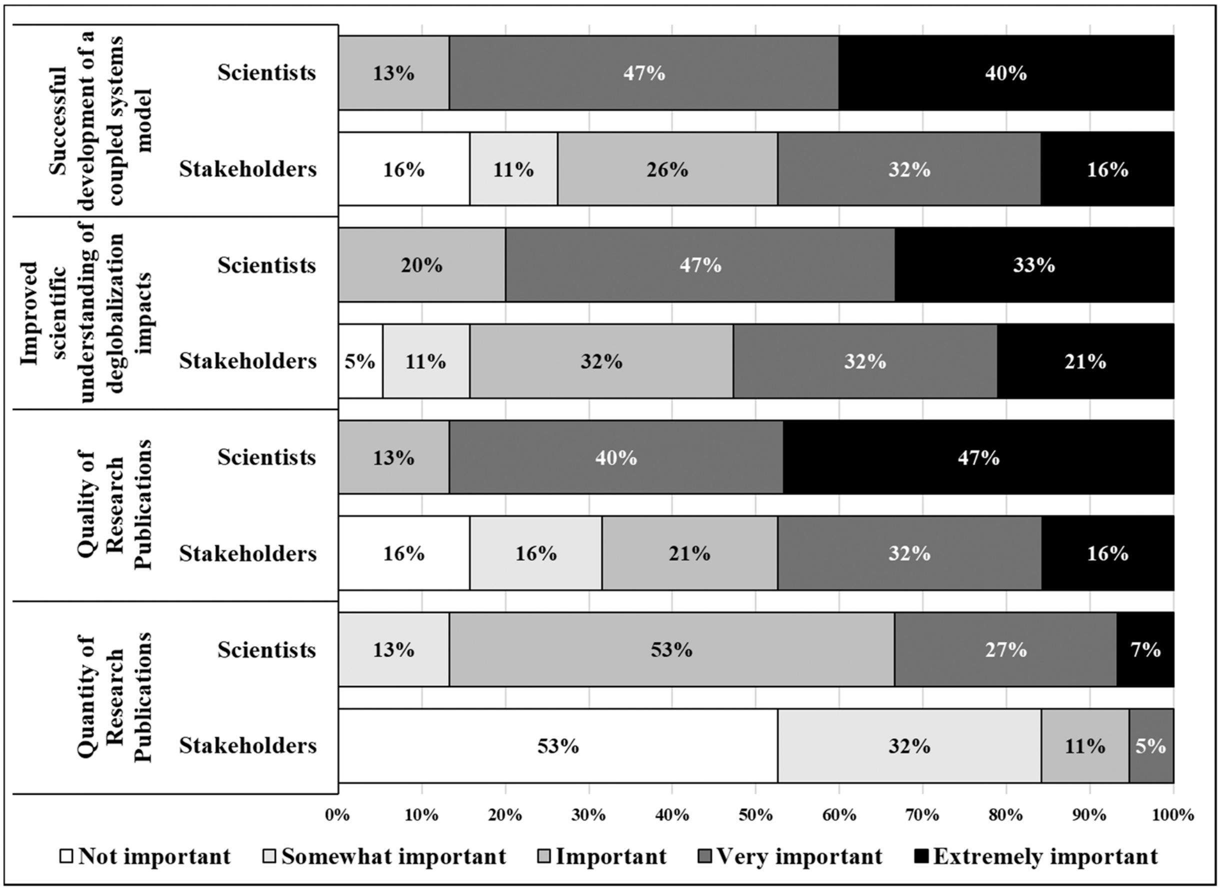

Fig. 2. Perceived importance of various scientific outcomes from the DRFEWs project, percent of survey respondents by type of participant.

that the quality of research publications and development of a coupled systems model was very or extremely important, compared to 48% of stakeholders. A similarly higher proportion of scientists than stakeholders ranked the goal of improved scientific knowledge about the impacts of deglobalization on the region as an important outcome from the project. Scientists also valued the quantity of research publications more highly than stakeholders.

The qualitative interviews provided a more robust window into the types of scientific outcomes that were most valued by academic science team members. When asked what outcomes were most important to this project, two-thirds of science team members gave at least one example of academic outcomes. These included:

> "Lots of intellectual outputs and a lot of academic outputs, lots of papers, models, things like that. That that is I think the bare minimum that we should get." (SCI-15)

> "At a strict academic level, I'd like to see some high-level publications come out of it. I'd like to see some graduate students' theses, dissertations get completed, post docs write some articles too." (SCI-2)

> "If you walk out of here with something that is publishable … developing this systems of systems model for our region that is general enough to handle shocks related to policy in the economy and whatever, society at large…the broad scientific achievement I guess. Which would hopefully be integrating three levels of systems in one model that can look at a particular locality and embed it within a region and embed that within a nation and then examine how shocks affect each type, which is cool." (SCI-10)

While most stakeholder advisors also recognized the value of academic outputs, they placed less importance on these and several indicated that they were moderately concerned that academic products may have limited impact if they are not readily applied to practical or real-world situations. Some typical comments in the interviews included:

> "If it's just kind of an academic study, it's going to have, it's not going to matter." (SH-29)

> "They reach out to all these different groups. Agriculture, business, you name it. You have all these metrics. We're so concerned that the metrics may not be meaningful." (SH-15)

> "I would like to see how to actually implement information or models. It is one thing to collect a lot of data and create something, but if people don't understand what to do with it, to be successful or how it impacts all the different partners that are contributing and how they can use it to enhance their individual activities, to me it doesn't, it doesn't move us forward. So I would like to see a practical way of implementing the models. And demonstrating and communicating the data." (SH-32)

As noted above, stakeholders also highlighted the importance of doing good science and developing a model that improves our understanding of the dynamics of the regional FEWs system as a key outcome. Examples include "*to develop a functioning model that reasonably captures various interactions*," *(SH-27)* "*to understand the relationship among the difference sectors," (SH-26)* and to *"be right at the end in what you predict*". *(SH-19)* In the interviews, stakeholders were more likely than scientists to list examples of the types of personal knowledge and understanding that they hoped the project would provide. These generally focused on whether the project is "*able to predict, with some level of certainty, the* *future outcomes*." *(SH-35)* One extended quote captures a vision of key outcomes that was echoed by many of the stakeholder respondents:

"Insights about what the implications of that kind of recalibration of the global economic system, what the implications of that are… trying to understand if the world were to move away from, sort of retreat from globalization, and have economies that were much more regionally focused and regionally based, from a physical resource standpoint, and from in terms of the market space or. What are the implications of that shift for people, principally, for society, but more particularly, what the implications are for the energy system, for the water system, for the food system. And of course, not each of them just by themselves, but how they then inter-relate. Because that's to me, the main goal of the effort." (SH-34)

While scientific outcomes (e.g., papers, degrees, new knowledge or methods) were valued, most project participants saw broader societal impacts as also important to the success of the DR FEWS project. In general, these societal outcomes were ranked as more important in the online survey by advisors than by science team members, though the differences were more nuanced (Fig. 3). Stakeholder advisors were particularly supportive of ensuring that regional decision-makers have greater trust and acceptance of the modeling results. Other important outcomes included heightened understanding of globalization and increased use of modeling results by decision-makers.

These views were also expressed and elaborated in the qualitative interviews. Consistent with the survey results, there was a generally greater emphasis on societal outcomes in the answers of stakeholder advisors than among the scientists on the team, as illustrated by the following representative quotes:

"I guess it would be that you have the information necessary for farmers to make decisions to change their practice, but also that you have their buy-in to want to change their practices." (SH-20)

"Primary outcome is that policy makers pay attention to this and consider it during their discussions (SH-35)

"(One outcome) may be that it would lead Congress or administration to change policy to help the country in a good way maybe… Hopefully this model would say, 'Hey, you can't do that or this is going to happen." (SH-19).

"Better adaptation by the stakeholders to climate change… So in other words, the people in this geographic area that are affected should have more tools and be better informed on how to adapt." (SH-30)

"And I see this research project in a way…would yield insights that would be valuable to decision makers. Not to say that deglobalization definitely is going to happen, but that if it happened, here are some of the implications, and here are some of the things we should maybe. the questions we should be asking and answering for ourselves. Be prepared." (SH-34).

While all scientists underscored the value of academic/intellectual outputs in their interviews, many also pointed at the importance of getting our findings into the hands of regional decision-makers. While this information may not always be used, the hope was that the project's findings would be able to produce better decisions with more sustainable outcomes in the region. Example quotes include:

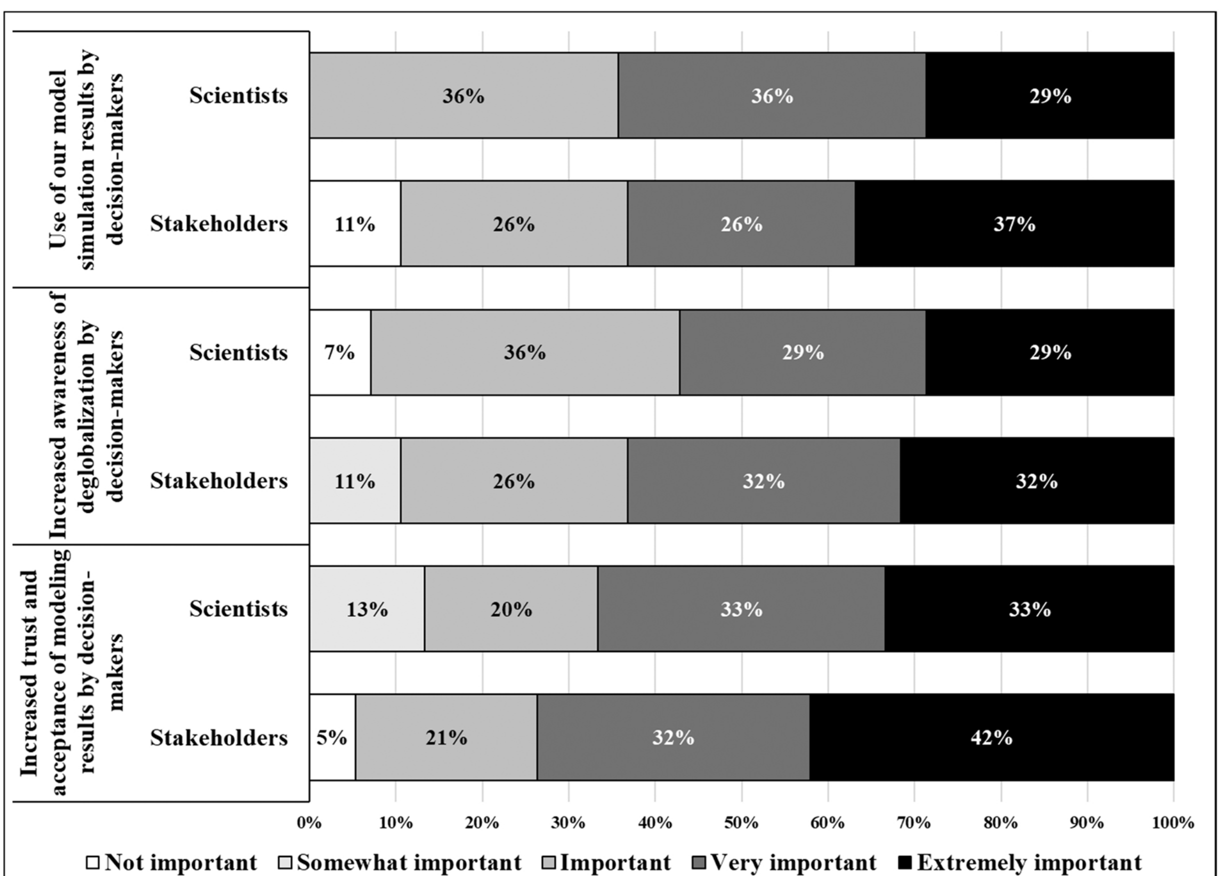

Fig. 3. Perceived importance of various societal outcomes from the DRFEWs project, percent of survey respondents by type of participant.

"So getting that information to people who actually can make applied changes and not keeping it strictly within the academic realm, I think is really important." (SCI-4)

"I think the most important objective of this project is to provide some good guidance to this society, to this region to make their decisions in the face of future uncertainty. So that's why we provide this guidance or support information for the regional government and our regional farmers, these people, so they can get some good information to help their decisions. I think this is important for society." (SCI-1)

"I think the outcome of this project will help people make better decisions based on the information provided by the model… help stakeholders make decisions in the future… I would hope that there is some information that can be gleaned from it to say, 'You know what? You're never going to be able to put enough money into this idea to actually change that behavior because there's just too much resistance out there to changing change." (SCI-14)

Aside from conveying information, data, models, and tools to decision-makers, a handful of stakeholders (but none of our scientists) pointed at the importance of the project producing tangible outcomes on the ground, including "*profitability for the landowner or producer, along with keeping our environment sound and safe," (SH-18) "clean air, clean water, and healthy foods…a stronger economy," (SH-24)* and *"a transformation of the energy system in the Great Lakes states to more renewable and less environmentally impactful energy supplies." (SH-25).*

3.4. Likelihood of achieving outcomes

In addition to capturing which objectives were listed as important by project participants, our online survey also probed the degree to which our team's scientists and stakeholder advisors felt that these outcomes were likely to occur by the end of the DR FEWS project. Results suggest that scientists and stakeholders had different views about the likelihood of some key outcomes (Fig. 4). On the one hand, scientists were more likely to think that the project would improve scientific knowledge about the implications of globalization on this region, with over 60% of scientists indicating this was 'very likely' compared to only 24% of the stakeholders. A significant majority of all respondents felt it was likely or very likely that the project would produce usable information and tools, but scientists were more optimistic in this regard than stakeholders. On the other hand, scientists were more pessimistic than stakeholders about the likelihood of information actually being used by decision-makers (20% vs 35%), and only one scientist felt it was likely that the project will improve the resilience of the regional FEW system, compared to roughly 30% of stakeholder participants.

4. Discussion and conclusions

Transdisciplinary research (TDR) methods have been used to accomplish a wide range of scientific and non-scientific goals and outcomes (Walter et al., 2007; Lux et al., 2019). The specific outcomes generated through each TDR project are influenced by the vision and goals of the original designers of the project (usually scientists), as well as the perspectives of scientists and stakeholders who engage in some or all stages of the knowledge production process (Bieluch et al., 2017). A number of studies have investigated how stakeholders feel about being involved in research and assessed different strategies to integrate them into TDR projects (Bracken et al., 2015; Brennan and Rondón-Sulbarán, 2019; Hunt et al., 2020; Klenk et al., 2017; Tobias et al., 2019). Others have documented the convergence of perspectives and communication

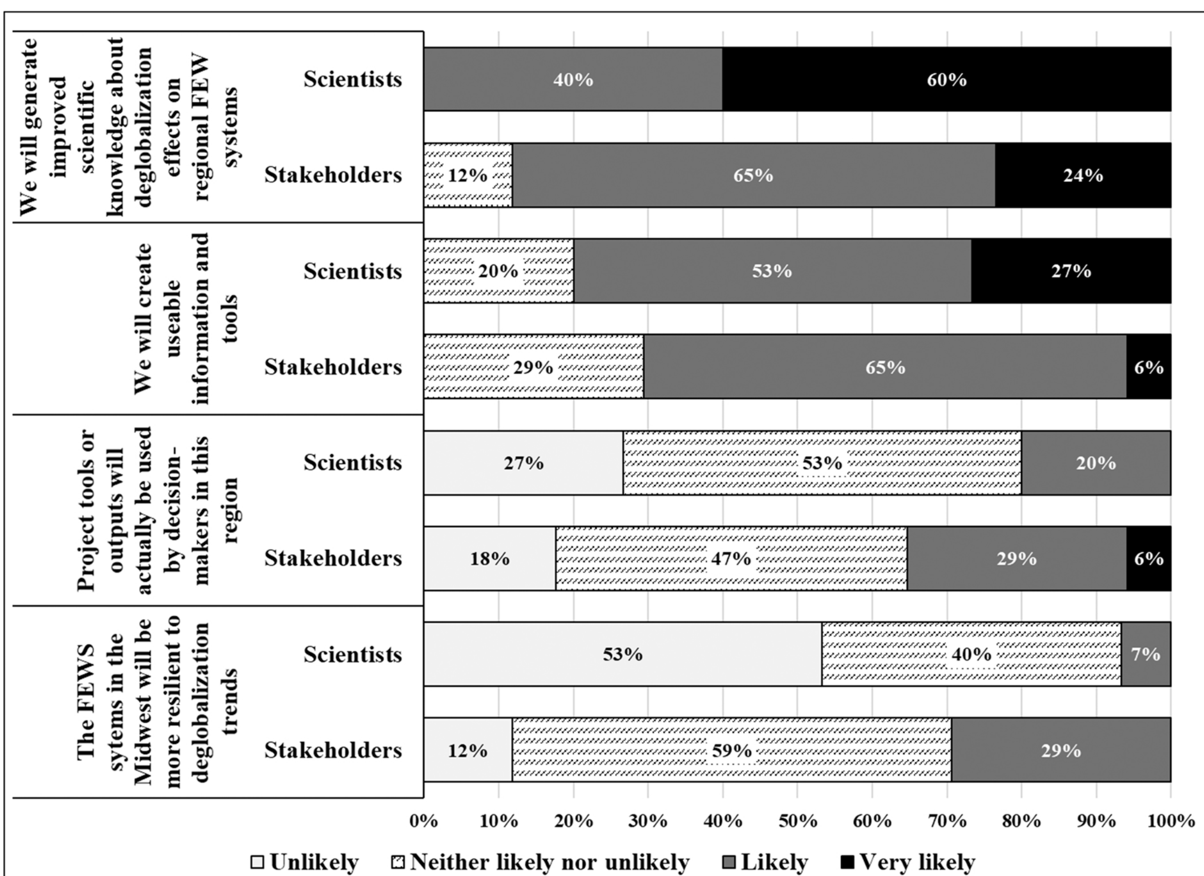

Fig. 4. Perceptions of participants about the likelihood of key outcomes from the DR-FEWS project.

patterns between scientists and stakeholders within working FEW systems (Daher et al., 2020). Relatively few studies have compared the perspectives of scientist/researcher and stakeholder/practitioner participants at the beginning of a TDR project (Thompson et al., 2017; Brennan and Rondón-Sulbarán, 2019), and the ways in which alignment of expectations may affect dynamics of the TDR process (Binder et al., 2020; Frescoln and Arbuckle, 2015; Hansson and Polk, 2018). Our research was designed to address this gap.

Overall, our findings suggest that motivations, understandings, and expectations among participants at the outset of a large TDR project can vary significantly. Not surprisingly, scientists had a greater appreciation for (and attachment to) the opportunities the project could provide to generate new scientific knowledge, innovative methods (e.g., coupled models), and the related outputs which are valued and rewarded in academic institutions (publications, graduate degrees, and prestige). Scientists on this project were also very excited to engage stakeholder partners to 'reality check' the assumptions behind their models and to test drive ideas for creating modeling scenarios and packaging the product outputs. The use of stakeholder input to help with problem framing and to improve the quality of the scientific research and models is consistent with the first two phases of a TDR process as outlined by previous literature (Pohl and Hirsch Hadorn, 2007; Brennan and Rondón-Sulbarán, 2019; Woltersdorf et al., 2019).

Stakeholder participants represented a wide range of perspectives from our regional FEW system. On a personal level, stakeholders were generally motivated to participate to have an opportunity to listen to and engage in stimulating dialog among experts (both academic and non-academic) and to learn things that could help them make decisions in their regular jobs. These personal rewards are not uncommon motivations for participation in engagement processes, where both scientists and stakeholders have expressed interests in gaining a deeper understanding of each other, as well as building relationships, trust, and networks (Dilling and Lemos, 2011; Ferguson et al., 2018; Mader et al., 2013; Sol et al., 2013).

Both types of participants believed that this project should aspire to provide insights and information that would be helpful to decision-makers as they adapt to changing economic and environmental conditions and work to improve sustainability outcomes in the region. For scientists, there was explicit hope that by sharing emergent research and modeling methods and decisions with stakeholder partners, the project outputs would be more likely to impact regional decision-makers. This was expected to occur not only because they would be tailored to address concerns of real world actors (Lux et al., 2019) but also because stakeholder participants would themselves validate and disseminate findings through their networks (Nagy et al., 2020). Stakeholder participants generally embraced those roles but placed even greater emphasis than scientists on the importance of generating practical (and not academic) outputs, like actionable knowledge and useful tools that would be useful to regional decision-makers. That being said, perhaps because they had seemed similar projects fall short in the past, stakeholders in our interviews were actually more pessimistic than scientists that regional decision-makers would actually use this information at the end.

One area where our project's scientists and stakeholder expectations were less clearly aligned was related to the nature and depth of the contributions of stakeholders would be making to the final project coupled models. A number of scholars have developed typologies to discriminate between different dimensions and degrees of stakeholder participation in research (Cornwall, 2008; Johnson et al., 2003; Lambrou, 2001). These generally vary based on the degree of involvement and decision-making power given to stakeholders. At one end of the spectrum, scientists consult with stakeholders to get advice but retain full decision-making authority over research design and implementation (aka *consultative*). At the other end, scientists may advise stakeholders about research, but stakeholders retain the final say (aka *collegial*). In between there are *collaborative* approaches where *co-production* of knowledge is accomplished through a process where stakeholders and scientists stand on equal footing and make decisions collaboratively through a structured participatory process (Reed et al., 2018).

Combining the qualitative and quantitative input from both the scientists and stakeholders, it appears that most participants entered into this project with a default assumption that the role of stakeholders was to be consultative or advisory. Almost all participants expected scientists to make the key decisions, tempered by input and advice from our stakeholders. However, there were a subset of both scientists and stakeholders who viewed things through a more collaborative lens, in which stakeholder participants would be given a substantive role to shape final decisions about the focus of specific project scenarios, model assumptions, and sustainability assessment metrics. Both scientists and stakeholders noted the novelty of our participatory approach to develop a model of a regional FEW system and appreciated the opportunity for stakeholders to help shape our methods and outputs from the outset. Overall, stakeholder participants were more likely to expect that stakeholder input would substantively impact the final models than did scientists, suggesting some potential for misalignment of expectations.

Our interviews also hinted at the enduring tensions related to the distinctive reward systems and different ways of knowing (or epistemologies) experienced by academic scientists and practicing stakeholders (Fry, 2001). As noted by Thompson et al. (2017), research scientists tend to be aligned closely with the normative values and career incentives that are rewarded by academic institutions, while stakeholders see academic research as a means to guide efforts to create useful solutions to societal problems in practice. Cook and Brown (1999) have argued the prevailing distinction between the 'epistemology of possession (knowledge)' and the 'epistemology of practice (knowing)' can be transcended through participatory engagement to create 'bridging epistemologies' as a way of reconciling areas of disagreement and integrating the value of each source of knowledge. At the early phase of our project, it was clear that work remained to be done to create processes and modes of interaction with stakeholders that would lead to knowledge that equally reflected contributions from academic and practitioner experts.

Ultimately, we believe that clarifying areas of agreement and misalignment of expectations can be important to successful TDR research projects. Enabling an adaptive process of dialog and reflection between scientists and stakeholder participants early in the process can help ensure that initial TDR objectives and goals (e.g., new insights, improved models, social learning, and societal impacts) can be accomplished (for useful examples – see Mitchell et al., 2015; Roux et al., 2017; and Woltersdorf et al., 2019).

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Douglas Jackson-Smith reports financial support was provided by US National Science Foundation.

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