The Pennsylvania State University

The J. Jeffrey and Ann Marie Fox Graduate School

UNDERSTANDING RESEARCHERS' POSITIONALITY IN INTEGRATING AND DESIGNING THE TRANSDISCIPLINARY RESEARCH PROCESS AND OUTCOMES: A CASE STUDY OF THRIVING AGRICULTURE PROJECT

A Dissertation in

Agricultural and Extension Education

by

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Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Doctor of Philosophy

December 2024

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ABSTRACT

Sustainability challenges, also known as wicked problems, are inherently complex, and developing solutions to these problems is beyond the capability of any single discipline. This necessitates collaboration among stakeholders with a 'stake' in these issues and their solutions. In response to these challenges, the transdisciplinary research (TDR) approach is increasingly employed due to its potential to tackle the complexity of these issues by integrating diverse disciplines and stakeholders.

The present dissertation presents three studies: The first study aimed to investigate the theoretical knowledge of TDR and transdisciplinary researchers (TD researcher) and the application of these concepts in a case study, i.e., the Thriving Agriculture project funded under the Sustainable Agricultural Systems (SAS) funding portfolio of the USDA NIFA. Out of 42 members of the Thriving Agriculture Project, 21 members agreed to participate in interviews for the study. The qualitative data were collected from the project's faculty members (n= 15) and graduate students (n= 06) from March to June 2024. Data were collected online *(*n = 19) and in person (n=02) and further recorded, transcribed, and analyzed. The salient findings showed a significant knowledge gap in the conceptual understanding of researchers about the concepts of TDR and TD researcher. TDR was understood as an interdisciplinary and multidisciplinary research approach. Our findings synthesized that TDR is a process that can address complex challenges by integrating diverse disciplines and perspectives of researchers and stakeholders while considering contextual factors such as social, historical, and economic.

Additionally, the components of TD researcher identity included their ability to solve problems, build collaborations, integrate diverse disciplines and stakeholders, understand contextual factors, and have personal motivation to address challenging issues. Research showed that the nature of complex challenges, opportunities for collaboration, research skills, and engagement with external stakeholders were some of the motivations for participants. The research also showed that motivations identified in the research were similar to advantages derived while working in the Thriving Agriculture Project (e.g., improving knowledge and skillsets, professional development, collaborations across disciplines, institutions, and external stakeholders). Nevertheless, the difficulty in understanding and managing projects, complex dynamics, understanding one's own positionality, time management, and logistical constraints were some of the hindrances encountered while working on the Thriving Agriculture Project. In the second study, we studied the conceptual understanding, application, and benefits of stakeholder participation and co-production of knowledge. We used a methodology similar to the one mentioned in the first study. Findings showed significant uncertainty and confusion about the stakeholder participation and co-production of knowledge processes. In light of the findings, we were able to define stakeholder participation as an active and iterative collaborative process aimed at supporting the researchers with current happenings outside the academic silos. From the application perspective, the stakeholders familiarize researchers with ground-level issues, help track project progress, refine the research process, share outcomes, and seek feedback. To researchers, stakeholder participation was a satisfying experience, but for a few, they did not show much satisfaction. Most researchers anticipate collaborating with existing stakeholders in the future, but discontinuance or conditional engagement was also found. The reasons behind the discontinuance or conditional engagement were subject to the availability of resources, stakeholders' interests, location, and project scope. In the case of the co-production of knowledge, participants benefitted in terms of their enhanced accountability towards stakeholders, expanding

research horizons, and stakeholder engagement, while the co-production was perceived to be beneficial for stakeholders as they gained access to scientific information, awareness of research issues, and networking opportunities. From both studies (I and II), the knowledge gap, i.e., lack of clarity and certainty in the case of TDR, TD researcher, stakeholder participation, and co-production, demonstrates the need for transdisciplinary research education and capacity-building programming. In response, funding agencies, institutional support, and capacity-building programs are essential to providing researchers with TDR's essential skills and knowledge to address complex challenges.

The third study sought to establish core competencies needed by evaluators for evaluating the TDR projects. The study involved a three-round modified Delphi study using a panel of 26 evaluators selected from 41 projects in the SAS funding portfolio of the USDA's NIFA grant program. The data were collected online using a Qualtrics survey and yielded a set of 60 competencies reflecting key areas of transdisciplinary research, data collection methods, ethical considerations, interpersonal skills, and program planning and management. There was 100% agreement for nine competencies, for example, conducting the responsible evaluations (i.e., ethical conduct, fairness, stakeholder engagement, and accountability). More specifically, the analysis of the competencies guided by the American Evaluation Association framework (2018) revealed that the majority of competencies fell into the categories of Methodology (31.7%, n=19), followed by Professional Practice (15%, n=9), context (13.3%, n=8), Planning & Management (10%, n=6) and Interpersonal (10%, n=6), the rest of competencies were specifically related to TDR and classified into a new category, 'Unique to TDR'. This category captured 12 competencies, such as understanding the theory and practice of TDR. Our findings guide TDR evaluators in considering these competencies while engaging in the evaluation pursuit. Understanding and applying competencies identified in the study helps draw attention to what needs to be in the toolkit of evaluators for evaluating TDR projects. Therefore, the funding

agency and capacity builders need to include and support these competencies in the skill development training programs for practical evaluation of the TDR projects.

Keywords: stakeholder participation, co-production of knowledge, conceptual clarity, transdisciplinary research wicked problems, Delphi study, consensus, program evaluation

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ACKNOWLEDGEMENTS

I am grateful to the almighty God for the tremendous opportunities and for making me see this day!!

I want to extend my deepest regards and thanks to my advisor, Dr. Anil Kumar Chaudhary, who has played an instrumental role in shaping my research identity, encouraging me to expand my limits, providing me with constructive and honest feedback, and ensuring that I am walking the right path for my personal and professional well-being. Thank you very much for your constructive role and for setting an ideal example of a true mentor, and leader. I am extremely thankful to you for your support, encouragement, and flexibility. Thank you for making my academic journey full of joy, passion, and enlightenment. Under your guidance, I have lived every day with growth and development. Over the three years, I have progressed both academically and personally. Your contribution has been great, and I truly acknowledge and will carry the legacy forward.

I am grateful to my dissertation committee, Dr. Mark Brennan, Dr. John Ewing, and Dr. Emily Pakhtigian, who have provided immense support, guidance, and feedback to improve the quality of this dissertation. I genuinely value this support and humbleness. Their invaluable suggestions, critical observations, and constructive feedback significantly improved the quality of my research and thinking process.

I am also grateful to my beloved parents and sisters, who are a major source of motivation, positivity, joy, and strength. Without them, I find myself nowhere. They have known me for the longest time, seeing me work harder to see this day and contributing substantially at levels to make sure. Staying away from loved ones is not easy; I thank you for your regular supply of strength, encouragement, and trust in me.

I also want to take this moment to extend my heartfelt regards to Dr. Rama Radhakrishna and Dr. Kaitlyn Spangler, who have enriched my knowledge through engaging discussions and sharing experiences. I sincerely regard Dr. Kirandeep Mann, Mrs. Rupinder Pal Kaur Brar, Dr. Sajjan Grover, Mr. Jaspreet Singh, and Dr. Meetpal Kukkal for their consistent motivation and contribution.

Seniors are ideal in the departments as they walk the identical path before their juniors and have several experiences and guidelines to share and support. I am extremely thankful to Dr. Elsie Assan and Dr. Halima Therese Gbaguidi A, who have supported me enormously academically and emotionally and were always there for me.

I sincerely thank my friends (this list is fortunately long, and you all are dear to me), who have tremendously supported and continuously encouraged me to improve. Thank you for listening to my endless stories and guiding me in making rational decisions in life.

I would like to thank the National Institute of Food and Agriculture (NIFA), the United States Department of Agriculture (USDA)[1] for supporting my PhD through Thriving Agriculture Project. Because of the tremendous support of the project, I could concentrate on PhD without any constraints and got ample opportunities to attend workshops, conferences, and meetings in different parts of the United States. I am thankful to the Thriving Agriculture Project team and all my research participants of the research. Without their support, this would not have become a reality. I wholeheartedly acknowledge your time, efforts, dedication, expertise, and input in my research. One of the greatest treasures of this academic journey also resided in the research and outreach work with Amish and Old-order Mennonites communities; I am fortunate to have gained

[1] This work is supported by Sustainable Agricultural Systems grant no. 2019-68012-29904/project accession no. 1019799 from the USDA National Institute of Food and Agriculture. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and should not be construed to represent any official USDA or U.S. Government determination or policy.

one of the unique experiences that continues to encourage me to work harder and inspires me to work at the field level for a wide range of communities.

I also extend my sincere regards to Dr. Maureen Reed from the University of Saskatchewan, Canada. Her support is highly regarded and contributory. Thank you for the opportunity to engage in the *TRANSECTS* project.

My special regards are to the Department of Agricultural Economics, Sociology and Education and Pattee and Paterno Library at the Pennsylvania State University, where I have seen many dreams and worked hard to translate them into reality.

Chapter 1
Introduction to the Dissertation

Introduction

Environmental challenges such as climate change, water resource management, and food insecurity are inherently complex and multifaceted (Walls, 2018). The challenges are often termed as wicked problems (Churchman, 1967), as these challenges lack a clear definition and readily identifiable solutions owing to interconnected factors, where one problem is a cause of another problem, i.e., outputs of one problem serve as input for another problem (Rittel & Weber, 1973). However, this term has been somewhat overused recently (Alford & Head, 2017). Despite the pervasive use of various disciplines to describe complex challenges, a consensus for theoretical grounding and uniformity of this term is not there (Lönngren & Poeck, 2021).

Addressing wicked problems is not limited to finding ultimate solutions but involves exploring improvements and approaches to tackle them. Consequently, the emphasis is placed on fostering problem-specific collaborations (Alford & Head, 2017). Timely management of environmental issues is crucial for the sustainability of nature and society. Therefore, cultural, structural, and practical transformations are required to achieve sustainable solutions (Frantzeskaki & De Haan, 2009). Transdisciplinary research (hereafter, TDR) is valued more than contemporary methods, such as mono-disciplinary, interdisciplinary, and multi-disciplinary approaches, due to their potential to address such challenges (Hansson & Polk, 2018). Consequently, research priorities shift towards TDR from conventional research approaches. Historically, the roots of TDR trace back to 1970, when it was conceptualized as "a common system of axioms for a set of disciplines" (Klein, 2004, p. 515).

The TDR approach requires attention from more than one discipline as the impact and implications of complex issues are multifaceted (Jahn & Keil, 2015; Klein, 2008; Max-Neef,

2005). TDR aims to co-produce knowledge by engaging different stakeholders in addressing complex problems (Hoffmann et al., 2017; Jahn et al., 2012; Lang et al., 2012; Lawrence & Després, 2004; Mauser et al., 2013; Pohl 2011). A recent definition iterates TDR as a "collaborative and integrative process approach that involves individuals from multiple disciplines working together to solve complex problems" (Lawless et al., 2024, p. 9). Thus, the TDR brings together academic and social perspectives (Clark et al. 2016; Fitzpatrick et al., 2023; Hoffmann et al., 2017; Norström et al., 2020; Pohl, 2011; Pohl & Hirsch Hardon, 2007). This shift towards broader approaches underscores the importance of knowledge co-production and decision-making (Lang et al., 2012).

TDR is recognized for addressing complex sustainability challenges by including multi-stakeholders across disciplines and levels. Kiatkoski Kim et al. (2022) highlight the suitability of TDR for resolving complex issues involving interdependent variables. The activities within TDR include setting a common agenda for research, formulating research questions, and disseminating results collectively with the stakeholders (Merkx et al., 2011; Woodall et al., 2021). Therefore, TDR emphasizes social and scientific outcomes (Kiatkoski Kim et al., 2022) to enhance useability of outcomes and achieve scientific and societal impact (Clark et al., 2016; Lang et al., 2012; Pohl & Hirsch Hardon, 2007) while engaging diverse stakeholders.

Stakeholder engagement in TDR

Stakeholder engagement is vital in TDR to ensure that research is both scientifically valid and socially relevant, and acceptable to ultimate users. Stakeholder engagement broadens researchers' awareness to research facets unknown to them and view of problems through social lens, that might remain unattended otherwise (Clark et al., 2016; Lang et al., 2012). Stakeholder engagement requires clear TDR goals and an understanding of the nature of contributions, project

stages, and stakeholder roles (Muhar & Penker, 2018). Schmidt et al. (2020) segmented stakeholder engagement into four categories based on research objectives - normative, social-learning, substantive, and implementation- originally conceived by Fiorino (1990). When the research objective is normative, stakeholders may contribute their ideas to enhance the research quality at any stage. The substantive objective considers stakeholder perspectives to understand the problem context and determine feasible solutions for improving the research quality. The social learning objective focuses on understanding needs and addressing problems, and empowering marginalized stakeholders (Jacobi et al., 2022). The stakeholders' legitimacy, trust, commitment, and contribution could be assessed during implementation. Additionally, the importance of the three aspects, accountability, impact, and humility, has been stressed for stakeholder engagement (Van der Hel, 2016). Accountability refers to responsibility towards society; impact refers to implementing science-based knowledge in society; humility denotes considering values, perspectives, and norms into scientific discourse. The stakeholders' contribution spans from identifying a problem to disseminating the results (Merkx et al., 2011). The stakeholders could contribute by informal interactions, consultation, participation, and productive interactions based on the research needs (Merkx et al., 2011). There needs to be a two-way understanding between the scientist and stakeholders (Polk, 2015).

Collaboration with diverse stakeholders could help develop knowledge rooted in social, cultural, and political contexts and inform policy decisions (Mitchell et al., 2006). The considerations include answering the questions, 'who' can contribute 'what' kind of knowledge in the 'which' phase of a transdisciplinary project and 'why'? (Muhar & Penker, 2018, p. 272). The 'Who' refers to a plurality of the actors involved in the research process and does not confine itself to actors only but also what roles they play in the TDR. The 'What' refers to the types of knowledge at various levels of the project. The 'When' refers to roles played by the different actors across varied phases of the research. The 'Why' refers to clarifying the roles of the

stakeholders. In establishing a rationale for stakeholder engagement, the researchers need to clearly understand ‘why’ they want to interact with stakeholders before determining ‘when’ and ‘how’ to do it (Knaggård et al., 2019). Clear stakeholders’ expectations are essential to prevent conflict related to their roles and responsibilities.

Stakeholder engagement in research design and implementation indicates the need for clearly defined roles. For TDR success, continuous stakeholder involvement and guidance at different levels of the project is needed (Woodall et al., 2021). Early involvement has been recognized as useful for making key research decisions (Edelenvos et al., 2011). Moreover, sufficient space and time are achieved to define research questions, methods, goals, anticipated outcomes, as well as modes of communication, benefits, and risks (Cvitanovic et al., 2016). Acknowledging the early involvement, the stakeholder can contribute during or after the project life cycle (Price et al., 2023; Woodall et al., 2021) or after the project (Price et al., 2023). Moreover, prior knowledge and personal interactions with stakeholders enhance the impact of stakeholder engagement (Molas-Gallart & Tang, 2011). However, achieving social and scientific outcomes in TDR contexts is sometimes challenging (Nagy et al., 2020). The perceptions and approaches to promote TDR among the researchers are not well-understood. Further exploration is needed to foster a more collaborative space for applying TDR (Lawless et al., 2024). The research application is increased when outcomes are relevant to wider stakeholders. This encompasses effective practices, including communication of results to co-production of knowledge (Knaggård et al., 2019).

Co-production of knowledge process

The co-production is a well-recognized part of TDR (Polk, 2015). Co-production of knowledge is a processes that iteratively bring together diverse groups and their ways of knowing

and acting to create new knowledge and practices to transform societal outcomes (Wyborn et al., 2019). However, sometimes, collaborative processes are synonymously used as co-ideation, co-design, co-implementation, and co-evaluation (Fitzpatrick et al., 2023). During this process, the boundaries of academic and non-academic stakeholders converge and get blurred, and their roles are exchanged (Pohl et al., 2010).

The role of contextual factors is important in co-production process. The context factors could be environmental, socio-economic, and political factors, societal norms and values of the stakeholders and researchers. Such contextual factors influence the stakeholder's interaction and co-production of knowledge (Norström et al., 2020; Pohl et al., 2017). It is often difficult to involve stakeholders in the research process (Woltersdorf et al., 2019). The challenge in TDR lies in producing actionable knowledge based on scientific evidence for the specific problem context (Lang et al., 2012; Norström et al., 2020). Cvitanovic et al. (2016) mentioned that the lack of organizational support to develop stakeholder engagement, balancing the engagement with other responsibilities and lack of financial support for the engagement pose barriers to co-production of knowledge. However, it is challenging to identify social actors who have similar interests and can assist in shared learning of the research problem (Luthe, 2017). Co-production with the stakeholders is far more complex than appears from the terminology. It is a long-term commitment that requires time, skills, and resources to build trust among the stakeholders (Woodall et al., 2021). Participant diversity in the research poses considerable difficulties in considering the perspectives of each stakeholder in a shorter span of time (Woltersdorf et al., 2019).

Given the complexity of the TDR context, the researchers need to understand the rationale for interacting with other stakeholders, the process, and the timing required for systematic stakeholder engagement (Knaggard et al., 2019; Stokols et al., 2006). However, challenges arise when bringing academic and non-academic stakeholders due to uncertainty about their interests,

questions, and representation in the problem's context. Understanding the stakeholders' roles, skills, and responsibilities (Hahn et al., 2023). The scientific community's contribution to TDR is not only limited to conducting discipline-specific research knowledge or solving problems but rather crosses the traditional boundaries of disciplines. This could be because the participants represent a wide array of disciplinary expertise that involves different vocabulary and meanings. Ultimately, the research aims to generate salient, credible, and legitimate information that can lead to desirable outcomes (Cash et al., 2003). Salience refers to how much information is relevant to stakeholders for decision-making. Credibility is linked to the accuracy of the information, while legitimacy is related to fairness in the research procedures. Moreover, the outcome of the TDR has also been mentioned as the improvement in the situation, generation and delivery, and mutual transformational learning (Mitchell et al., 2015).

Researchers' positionality in TDR

Positionality is linked with researchers' situatedness in the research, including biases, privileges, opportunities, and constraints. Positionality denotes where the researcher situates himself/herself in the research (Savin-Baden & Major, 2013). Researchers' intentions to engage stakeholders are influenced by their positionality and contextual factors, which influence the quality of TDR (Carew & Wickson, 2010). The variety of motivations for the stakeholders make significant contributions to the research (Boyle et al., 2023; Cerrato et al., 2018). Intrinsic and extrinsic motivations drive researchers' involvement in TDR, while personality attributes significantly impact interdisciplinary and regional/societal collaborations (Katoh et al., 2021). The broader motivations include impacting society through the utility of research findings (Boyle et al., 2023; Guimarães et al., 2019). In TDR, the primary motivation for engaging in research often stems from a desire to address issues that transcend the potential of single

discipline (Robinson, 2008). Apart from the motivations, in sustainability science, researchers' roles and activities have been broadly emphasized and classified into five categories: reflective scientist, process facilitator, knowledge broker, transition agent, and self-reflexive scientist (Wittmayer & Schäpke, 2014). The reflective scientist acts as an objective observer without direct intervention in the research process. The process facilitator enables and guides actions and learning among the research participants. A knowledge broker interlinks different perspectives of the stakeholders. The transition agent focuses on developing actionable change and motivating and empowering stakeholders. Lastly, a reflexive scientist critically examines his/her own positionality in the research process and opens to personal development during the research process (Wittmayer & Schäpke, 2014, p. 487-488). Horlings et al. (2020) introduced the concept of the embodied researcher based on roles and activities outlined by Wittmayer and Schäpke (2014). The embodied researcher takes up multiple roles throughout the research processes and engages in various normative roles such as envisioning research, following ethical principles, and expanding personal competencies and networks. These processes need to be understood to clearly articulate the research methodology, key roles, and activities of the researchers within the research.

The diversity of roles, actions, and expectations among researchers and stakeholders in TDR demonstrates the need to understand how participants fulfill their responsibilities and navigate differences within a collaborative space (Hall et al, 2014). They specified the roles and actions during the five stages of TDR: framing, launching, integrating, generating, and deciding. Beyond the specific roles of the researcher, the four broader categories of attributes are required for transdisciplinary researchers: key personality traits, skills and characteristics, risk-taking and institutional transgression, and details of the practices and respect for creativity and cultural relativism (Augsburg, 2014). Overall, understanding the roles, activities, and motivations helps to gauge the positionality of the researchers within the TDR context.

Research gaps in TDR

Despite being a recognized research approach, there are ambiguities about the nature and application of TDR. The TDR is understood synonymously with interdisciplinary or multidisciplinary approaches, highlighting no consensus on the term and its use across disciplines (Jahn & Keil, 2015; Lawrence, 2010; Lawless et al., 2024). The TDR methodology evolved from different methods combined from multidisciplinary and interdisciplinary methodologies to meet needs of current research and varying perspectives of the stakeholders (Wickson et al., 2006). The research problems in TDR are 'in the world and actual', indicating that TDR problems are selected from real-world contexts (Wickson et al., 2006).

Assessing the epistemological and ontological grounding of researchers engaged in the TDR is important. The roles of transdisciplinary researchers are not standalone, they are dynamic and ever-changing (Bulten et al., 2021; Hilger et al., 2018; Wiek, 2007; Wittmayer & Schäpke, 2014). Recent research has examined how TDR researchers identify themselves (Hakkarainen et al., 2023). A critical understanding was built on whether the researchers identify as sustainability researchers versus those who do sustainability research. The point of interest here is the positionality of the researcher. Hakkarainen et al. (2023) examined the difference between 'being' and 'doing' sustainability research. However, few studies have examined the perspectives of individual researchers working in TDR teams (Augsburg, 2014; Boyle et al., 2023; Fam et al., 2017). Clarifying roles include decisions about whom to involve, when to involve, how to involve, and how much involvement is needed for effective collaborations (Hilger et al., 2021). Research has focused on the researchers' roles and motivations, but the limited effort to document the perception of the transdisciplinary collaboration, barriers, and enablers for conducting the successful TDR collaboration has been documented (Kaisler & Grill, 2021). Clear guidance on attributes of transdisciplinary researchers, processes within the research, and

attempts to achieve the success of TDR is needed. Considering the application and potential scale of impact, it is interesting to know what types of motivations, e.g., intrinsic or extrinsic motivations, drive researchers to take up TDR initiatives.

More research is needed to understand researchers' personality attributes, their relationships, and outcome orientation of the TDR. Despite the definition, there are a wide array of thoughts on the identity of the transdisciplinary researcher. To illustrate, who is called a transdisciplinary researcher, whether any individual researcher could be called as transdisciplinary researcher, or any collaboration with other disciplines or between the communities is an indicator to be called as transdisciplinary researcher (Wickson et al., 2006). To the best of our knowledge, existing literature lacks a clear definition of the transdisciplinary researcher. Despite increasing emphasis on TDR, there is still limited evidence on the perception of TDR teams on transdisciplinary collaboration (Lawless et al., 2024). To fill in the missing pieces of our understanding of TDR, we need to ask ourselves: Who exactly is a transdisciplinary researcher? How do these researchers see themselves? And how does their self-perception align with their broader understanding of the role? To get a more complete picture, we should also talk to researchers actively involved in transdisciplinary projects and using methods like stakeholder participation. By doing this, we can gain valuable insights into the real-world experiences and perspectives of those working at the intersection of different disciplines.

The central role of the researchers and stakeholders remains ambiguous due to varied perspectives and motivations as well as research processes, outcomes, usability, and impact. There is limited knowledge of the perception of the researchers regarding various perspectives around the TDR (Zscheischler et al., 2018). It is imperative to determine how do researchers view the overall success of TDR. For example, whether the researchers experience difficulty and confusion in determining how TDR outweighs other research approaches (Zscheischler et al., 2018).

Concerns have been expressed over the wide array of terms defining the purpose, nature, process, and components of TDR. Nevertheless, knowledge co-production component distinguishes TDR from other approaches as TDR focuses on designing methods and practices for the future (Defila & Giulio, 2015). However, there is a lack of a common definition that amalgamates all the concepts related to transdisciplinary knowledge co-production. The current literature highlights the void for a universally agreed term to define a co-production of knowledge (Tembo et al., 2021). The term co-production of knowledge is scattered with a broader focus on generating new knowledge (Blackstock et al., 2007; Lang et al., 2012; Pohl, 2008). Metz (2015) simplified how different terms are used across disciplines, yet no clear boundary exists. It is essential to understand how the stakeholder participation and co-production of knowledge are conceived and applied in the TDR context, and overall success is envisioned. Having this information would facilitate the exploration of the link between theory and practice. To narrow these gaps, our research aims to collect first-hand data from the researchers on stakeholder participation, co-production of knowledge and implications of TDR and its impact on science, society, and policy. Beyond knowledge production, there also needs to be an understanding of how co-produced knowledge is scientifically, socially, and policy-wise valid.

Moving forward from researchers' positionality and conceptual grounding of core concepts of the TDR, investigating the perception of envisioning and realizing the scientific and social research impact of TDR is also scientifically significant. Even though the TDR has been increasingly employed in various sectors, the ideal TDR still needs to be understood (Carew & Wickson, 2010). Concerns primarily emerge due to lacking common terminology, communication channels, and shared research framework (Brandt et al., 2013). Despite several frameworks and approaches in the literature, there is still vagueness on what could be gleaned from different approaches while planning or implementing TDR (Lang et al., 2012). Establishing sound criteria to uphold research rigor in the TDR emerges as a crucial need. Without such robust

criteria, the evaluation of TDR may compromise the ability to estimate the quality of TDR (Belcher et al., 2016). Consequently, this vacuum of quality criteria leaves the evaluators and funders to rely on the pre-existing disciplinary measures that do not align with the context of TDR (Belcher et al., 2016). The community of peers able to review the quality of TDR endeavors is not well established (Wickson et al., 2006), indicating the need to develop skillsets and formalized approaches for evaluating TDR.

Guided by extant literature, this present investigation attempted to understand how the personality and positionality of a researcher shape knowledge co-production processes, outcomes, and impacts. The specific research questions guided this dissertation include:

1. To what extent do researchers' attributes (knowledge, motivations, advantages, and challenges) affect the success of TDR?
2. What is the perception of researchers about stakeholder participation, co-production of knowledge, and their application?
3. What are the core competencies needed by transdisciplinary evaluators to evaluate the transdisciplinary research projects?

Conceptual framework of the study

This dissertation examines researchers' positionality, such as knowledge of TDR and transdisciplinary researcher. The research includes motivations, advantages, and disadvantages of engaging in the TDR. The research also captures researchers' understanding of stakeholder participation, co-production of knowledge, and impact and implications for science, society, and policy. Additionally, the research aims to build consensus on the core competencies for the TDR evaluation. The dissertation is broadly guided by multiple frameworks such as the ideal-typical

framework (Lang et al., 2012), the TD Wheel (TDW) framework (Carew & Wickson, 2010), and the transdisciplinary outcome spaces framework (Mitchell et al., 2015).

The above-mentioned frameworks were considered suitable for answering the research questions. First, the ideal-typical framework (Lang et al., 2012) facilitates retrospectively and futuristically scanning how precisely the principles of the TDR befit across different project phases. The different project phases include Phase A (building research team, shared learning, and forming methodologies), Phase B (delegation of the role for the researchers and stakeholders), and Phase C (generating tangible and intangible findings and impact for science and society). To simplify, Lang et al. (2012) showed 'what' and 'how' researchers from diverse disciplinary backgrounds build collaborative environments, define roles and boundaries for scientific discourse, use methodological underpinnings, share knowledge, and produce tangible and intangible results for wide stakeholders. Further, the TD Wheel (TDW) framework is a comprehensive tool that offers strategic guidance to assess the quality of TDR processes and potential impact (Carew & Wickson, 2010). The framework encompasses three essential components of TDR namely *contexts* (e.g., problem context, research context, and researchers/s context), *process* (e.g., intention to engage the stakeholders, researchers' capacity, personality types, and responsibilities) and *product* (e.g., research outcomes). The context is classified into problem context, research context, and researcher/s context. The problem context refers to contestation for the stakes, complexity and uncertainty associated with the problems and ability of the researcher to access the problem. In addition, the research context includes funding availability, team members' location, communication mode, and power dynamics. The researcher/s context includes the researchers' prior experience, skills, and intentions for stakeholder collaborations. The researcher/s context also entails researcher own efforts to identify his/her positionality amid the scope of TDR.

Secondly, the *process* within the context of TDR is profoundly guided by the researchers' positionality in the research. This unfolds individual and collective factors, such as resources, researchers' skills, experiences, and motivations. The role of the context of the research problem and processes are intertwined, where both aim to produce collective success towards a broader goal. The process within the TDR also emphasizes reporting how the researchers view the stakeholder collaboration in the research. Considering the nature of TDR, it is invaluable to advance knowledge on researchers' efforts, constraints, and intentions to engage with the stakeholders, design different interventions, and anticipate the impacts of the research (Carew & Wickson, 2010).

Given the situation, the intertwined role of researchers' positionality and context of TDR facilitate the prediction of tangible (e.g., publications) and intangible (e.g., problem-solving and mutual learning) TDR products. Mitchell et al. (2015) advanced understanding of the transdisciplinary outcome spaces in three spaces: situation, knowledge, and learning. Firstly, the changes in the situation are broadly covered as changes in socio-institutional conditions, policies, and the biophysical environment. It is important to report on the role of researchers and stakeholders in changing the situation within and beyond the project life. Secondly, the changes in knowledge are linked to evoke desirable change in the stakeholders through publications and conference presentations. Lastly, mutual and transformational change is associated with long-term changes beyond the project life cycle. Mutual learning is related to building the capacity of direct and indirect recipients of the researchers to address the problems differently, whereas transformational learning is related to changes in practices of doing things differently (Mitchell et al., 2015). These frameworks have commonality, overlapping areas, and synergistic fit to evaluate scientific and societal impact (Carew & Wickson, 2010; Mitchell et al., 2015).

Furthermore, Woltersdorf et al. (2019) expanded the framework of TDR (Carew & Wickson, 2010), which was supported by the criteria and targets to evaluate the contexts,

processes, and products. By using both evaluative frameworks (Carew & Wickson, 2010; Woltersdorf et al., 2019), the current research intends to address the research questions. The rationale behind following these frameworks was to estimate the linkage among the TDR inputs, processes, and potential outcomes. Further, the study also explored the advantages and difficulties associated with each of these roles and the potential impact on the researchers' productivity.

This research aims to discover how researchers perceive the impact of their research on science, society, and policy. To achieve this, seeing how they share their research findings with scientific and non-scientific stakeholders was imperative. The research findings also aim to understand whether the project goals are intrinsically or extrinsically motivating for the researchers (Katoh et al., 2021) and reflective and reflexive actions (Schmidt et al., 2020). The research broadens understanding of what role the researcher plays toward the success of a research effort and elucidates the researchers' role in applying the new information to the problems' context (Wall et al., 2017).

The broader research goal is to document the perception of the researchers associated with the Thriving Agriculture Project regarding how they feel (e.g., perceived motivations and challenges) about being a part of the TDR project, how their activities fit into the broader context of the TDR, and how precisely tenants of the TDR have been followed. As the Thriving Agriculture Project was in an active stage, the main interest was to document the current state of the process that is taking place to achieve the social effects (Hoffman et al., 2017; Molas-Gallart & Tang, 2011; Nagy et al., 2020). Moreover, the research does not only aim to document the discrepancy between the perceived and intended participation of the researchers (Hahn et al., 2023). Backed by scholarly literature, the frameworks have scientific robustness and scope for reporting reflections of researchers on different research components. This research aimed to understand the positionality of the researchers' attributes (e.g., understanding of the TDR, transdisciplinary researchers, motivation, advantages, and disadvantages) and researchers'

positionality (e.g., stakeholder participation, co-production of knowledge, and their application). Additionally, the researchers sought to collect evidence on whether those researchers engaged in TDR identify themselves as transdisciplinary researchers. This examination explored their positionality within the TDR project and their research orientation.

Structure of the dissertation

Grounding the research inquiry on TDR, the dissertation is divided into five chapters: an introduction, three paper chapters, and an overall conclusion and recommendations chapter. The first chapter broadly covers the introduction, research gaps, need for the study, research questions, conceptual framework, and study methods.

More specifically, this dissertation focuses on three essays, a) To what extent do researchers' attributes (knowledge, motivations, advantages and challenges) affect the success of TDR? b) What is the perception of researchers about stakeholder participation, co-production of knowledge, and their application? c) What are the core competencies needed by transdisciplinary evaluators to evaluate the TDR projects? To respond to these questions, the United States Department of Agriculture's (USDA) National Institute of Food and Agriculture (NIFA) project, i.e., "Thriving Agricultural Systems in Urbanized Landscapes" (*Thriving Agricultural Systems in Urbanized Landscapes*, n.d.), was selected as a case study.

Thriving Agriculture Project

The Thriving Agriculture Project is a six-year project sponsored by the USDA NIFA's Sustainable Agricultural Systems (SAS) program from 2019-2025. The project aims to contribute to developing economically and environmentally thriving agricultural systems located on the

fringes of the urbanized landscapes in the Chesapeake Bay Watershed. The project team included 16 research groups from diverse disciplinary backgrounds and institutions located in six major states of the Chesapeake Bay Watershed. The scientific research team contributed expertise from various disciplines, including economic modeling, market analysis, watershed-scale nutrient management, and land use modeling. The project entailed Penn State, the University of Maryland, Virginia Tech, Ohio State, Utah State, George Washington University, the Stroud Water Research Center, and a stakeholder advisory board. Acknowledging the need and significance of a stakeholder advisory board, the Thriving Agriculture Project organized several stakeholder engagement events in various states of the Chesapeake Bay Watershed. These events aimed to share the research process, progress, and ground realities of issues affecting the Chesapeake Bay Watershed. The project's specific problem, diverse disciplines from multiple institutions, stakeholders' involvement, co-production of knowledge, and its scientific and social impact make it an ideal case to understand the convergence of different scientific forces and stakeholders in achieving sustainability in agriculture systems in urbanized landscapes of the Chesapeake Bay Watershed (Jahn & Keil, 2015; Klein, 2008; Max-Neef, 2005). Workshops with various stakeholders were conducted to seek their input; for example, scenarios for the project were developed and refined with the guidance of the stakeholders. Apart from this, a listserv was primarily used as a mode of communication to inform the project members of routine activities.

Organization of dissertation chapters

With the first chapter as a dissertation introduction, the second chapter expands on understanding researchers' perception of their knowledge, motivations, advantages, and disadvantages/difficulties in engaging in TDR. More specifically, the knowledge component included the researchers' knowledge of TDR, transdisciplinary researchers, and their self-

identification as TD researchers. Understanding the significance of researchers' positionality is crucial to determine as it outlines the information to what extent researchers understand the concept of TDR. This research approach has been critiqued for confusion and has inherent difficulties owing to the diversity of disciplines and levels involved. However, the research includes a variety of social and scientific implications. Therefore, it becomes necessary to determine the current understanding of the researchers who are currently a part of the TDR. Having this understanding further unfolds application of these concepts and difficulties, which is assumed to enhance transdisciplinary collaborations, capture funders' attention and educational infrastructures to develop transdisciplinary knowledge among researchers to meet the increasing demand of TDR in the current scenario. Researchers need to know where to position themselves and understand their roles, responsibilities, and capabilities in TDR (Peters, 2013). The investigation pertains to knowing how the researchers intend to reflect on their experiences and positionality related to TDR. The primary research question of this essay was: To what extent do researchers' attributes (knowledge, motivations, advantages, and challenges) affect the success of TDR? The research has the following objectives:

1. To determine the knowledge of concepts of TDR and TD researcher.
2. To determine the researchers' motivations to engage in the TDR.
3. To understand the perceived advantages of being a part of the TDR.
4. To understand the perceived challenges/disadvantages of being a part of the TDR.

The third chapter explored a conceptual understanding of stakeholder participation and co-production of knowledge and the perceived or desired impact of research benefitting the science, society, and policy and dissemination strategies for sharing the research across academic and non-academic stakeholders. This chapter primarily aimed to connect conceptual knowledge regarding stakeholder participation and co-production of knowledge and application in the Thriving Agriculture Project. Broadly, the essay has been built on the research question: What is

the perception of researchers about stakeholder participation, co-production of knowledge, and their application? The research has the following objectives:

1. To comprehend the researchers' understanding of the stakeholder participation and the status of the stakeholder participation in the TDR.
2. To comprehend researchers' perception and implementation of the co-production of knowledge.

The second and third chapters follow an identical methodological approach though each essay addresses distinct research questions. The descriptive case research design was used for these two chapters, considering the Thriving Agriculture Project, as a single case or investigation unit (Gerring, 2004). The case study refers to, "*a empirical enquiry that investigates a contemporary phenomenon within real life context, especially when the boundaries between the phenomena and context are not clearly evident"* (Yin, 2014; p. 16). By nature, the case studies intend to *explain, explore,* and *describe* the phenomenon (Yin, 2009). According to Simon (2009), the case study's purpose is to explore the diverse perspectives related to the complexity and unique features of the project. Thus, it is defined as "*inquiry that includes the different methods of the research to develop knowledge for the deep analysis of the program, policy, institution, system to generate knowledge, for the policy-based decisions, professional or community action*" (p. 21). The focus of a case study is to produce knowledge on a complex issue of real-world complexity (Crowe et al., 2011, p.1). In the second and third chapters, the overarching aim was to engage in a descriptive case study to glean information about the multifaced nature of the phenomenon (Yin, 2014).

Target population and sampling techniques for the second and third chapters

The target population for the second and third chapters includes researchers of the Thriving Agriculture Project. The researchers' group includes faculty, graduate students, and postdoctoral fellows. At the time of the investigation, there were 42 researchers working across the 16 research teams. Of which, I and faculty advisor were excluded as they were directly involved in the dissertation research. The sample was collected from the 40 project researchers. Therefore, a total of 13 faculty and 08 graduate students participated in the research, representing a total of 21 participants for the research. The faculty members in the research were appointed at various levels, from assistant professor to full professor, while graduate research students enrolled in master's and doctoral degree programs. Considering the specificity of the population, the census was used so that maximum responses and a variety of perspectives about research questions could be collected. An initial email stating the background, purpose, and significance of the research was shared with all the potential participants. Upon their consent to participate in research, a common time was found to meet via Zoom or in person. All the interviews, except two, were conducted on Zoom. The interview was blocked for two hours. Three participants agreed to meet only for an hour, and one participant for the 1.5-hour interview. The participants had a chance to read the interview protocol and consent forms well before the interview. Prior consent was obtained to record the interview and publish the findings in an aggregate (Kaisler & Grill, 2021).

Data collection instrument and process for the second and third chapters

The comprehensive research instrument based on the existing literature was used to collect data for second and third chapters (André et al., 2023; Boyle et al., 2023; Brennan &

Rondón-Sulbarán, 2019; Carew & Wickson, 2010; Lang et al., 2012; Wall et al., 2017; Wittmayer & Schäpke, 2014; Woltersdorf et al., 2019). The interview schedule includes several questions related to a fundamental understanding of researchers regarding TDR, e.g., c*ould you explain your understanding of TDR?* Furthermore, the stakeholders' satisfaction with TDR from the stakeholder was assessed with questions, e.g., *how do you currently involve or plan to involve them in the research?* To understand how the co-production of knowledge is being conceived and applied by each research team, the questions included, e.g., *a) according to you, what different modes of co-production are being used in this research? b) at which stage of the project do you think stakeholders should be included in the research activities? Please elaborate why do you think so? c) How do you see that knowledge co-production in project is achieving broader goal of the project?*

From the validity perspective, the interview protocol was sent to the dissertation committee and external reviewers (e.g., environmental sustainability, environmental sociology, transdisciplinary research, environmental governance systems, community development, stakeholder engagement, ecosystem science, and management) for their feedback. The recorded interviews were transcribed using Otter.ai software. The identifiers, such as names of researchers, stakeholders, and institutions, were removed from the transcripts to ensure anonymity and maintain the confidentiality of the data. The three transcripts were randomly selected and read well to understand the data. The data were coded to answer the research questions and identify the patterns and emerging ideas (Yin, 2014). The coding process involved both inductive and deductive processes. The initial process involved developing codes closer to the interviewee's responses. The codes were collected to understand the meanings, expressions, and intents, which were later emerged, segregated, or deleted in the direction of answering the research questions and developing a code book. The code book was continuously updated based on the identification of newer codes and revision of the prior codes. For example, the second coder was not well-

versed in the interviews and transcripts. Therefore, the understanding about the data was only based on the transcripts. The second coder independently coded previously selected three transcripts for each chapter and discussed the codes with the first coder for discrepancies and understanding of the meaning of excerpts, definitions of the codes, and language of the codes. Based on this discussion, a consensus on the codebook was achieved. The remaining transcripts were coded in the agreed code book, and new codes were generated wherever needed throughout the coding process.

Data analysis for second and third chapters

This descriptive case study involves coding and identifying themes (Saldaña, 2013). Initially, descriptive coding was used. During the descriptive coding, the transcriptions were open-coded in the first round of coding (Corbin & Strauss, 2007), which means that codes were developed by reading the scripts, understanding the meaning, and reporting the codes as expressed in terms and expressions by participants. In the second cycle of the codes, axial coding was employed, where initial codes were reviewed, combined, and developed into bigger codes (Strauss and Corbin, 1998) to formulate the patterns and themes. In this cycle of coding, axial codes were performed to merge codes into broader categories. This includes developing patterns from identical sets of codes and representing them in a story (Saldaňa, 2013). The information that may not contribute to answering the research questions was omitted. This is essential to identify emerging common patterns of the codes to synthesize in different themes (Creswell & Poth, 2018). Initially, the open coding was done throughout which was later compared to identify the similar codes followed by merging into developing themes. In this process, themes were clubbed to form a category (Braun & Clarke, 2006). The entire data was visited repeatedly to understand and confirm that coding is taking place as per the research goals. By visiting the data

repeatedly, we immersed ourselves with the data to identify the meaning, and patterns and answer the research questions. Once all the transcripts were coded, the data was seen through a comprehensive lens to identify the long list of codes throughout the data set. This included combining various codes which convey the same meaning (Braun & Clarke, 2006).

Validity of the research instrument for second and third chapters

From the qualitative aspects of the research, dependability and trustworthiness was established through four approaches: credibility (i.e., truthfulness), transferability (application to other research scenarios), dependability (i.e., replication of the research findings), and confirmability (i.e., confirming that research findings are free from any researchers' bias, and prejudices, and emerged from the views of the participants) (Lincoln & Guba, 1985). As both the researcher and participants belong to the same project, it makes it possible to employ members to check to determine whether reporting of events, facts, data, and interpretation has been correctly done (Lincoln & Guba, 1985). In addition, transferability is related to a thick description of the findings, which means that research findings have the potential to be used and applied in other contexts. The confirmability denotes how the research has evolved over time and reported each stage critically. In this case, the confirmability of the research findings was established by making field notes, writing memos, and personal reflections. Audit trailing was also done (Sandelowski, 1986) to ensure that future researchers can follow the decision-making process at the various stages of the research. For the credibility of the findings, panel testing of the interview protocol was conducted to ensure all the questions included in interview protocol address research questions sufficiently.

The fourth chapter (i.e., Delphi study) identified competencies for TDR evaluators. The nature of TDR is to address a complex problem, whereas the evaluation of TDR provides an

account of how far different research processes have been fruitful in addressing the problems. To have this happen, it is crucial to understand what skillset the transdisciplinary evaluators should possess so that evaluation is conducted rigorously. Prior research on the evaluation of TDR focused on principles and criteria for transdisciplinary evaluation, including relevance (i.e., usefulness of the findings to the society), credibility (i.e., accuracy, transparency, reflectivity, and reflexivity in the research methods, data, and interpretation of the findings), legitimacy (i.e., fair inclusion of stakeholders based on their interests and values), and effectiveness (i.e., potential to promote actions to address problems and offer solutions) (Belcher et al., 2016). Numerous evaluative criteria for the TDR have been mentioned (Blackstock et al., 2007; Belcher et al., 2016; Carew & Wickson, 2010; Jahn & Keil, 2015; Wall et al., 2017; Walter et al., 2007). However, the community of expert peers for the quality evaluation is missing (Wickson et al., 2006). Moreover, the evaluation competencies mentioned across the program evaluation are in general. Nonetheless, it is presumed that there are additional specific skills related to evaluating the TDR as it is multi-dimensional and complex. Therefore, identifying and consensus on competencies to evaluate TDR pursuits is crucial. Research needs to be conducted to determine which programs could teach these skills, how these skills could be stimulated, and which mediums could be used to stimulate the transdisciplinary skills (Fam et al., 2017). The evaluations are very case-specific; however, in the parallel universe, concerns are related to understanding the TDR itself but not the transdisciplinary evaluation. The research aimed to answer: what are the core competencies required for TDR evaluation?

To address this question. a Delphi technique was employed to gather input from a panel of experts in the field. The Delphi technique is valuable for seeking anonymous opinions from experts on a given topic (Dalkey & Helmer, 1963; Dalkey, 1972). The panel of experts was formed by identifying and inviting individuals actively engaged in sustainability research in agriculture from diverse geographical regions (Fam et al., 2017). The panel of six participants

was selected based on their expertise and active involvement in sustainability-related agricultural research. As this research uses the Thriving Agriculture Project as a case study, all the projects that were sanctioned in a similar cohort of SAS grants were selected. Each project has a team of external evaluators evaluating the TDR projects, and these evaluators were invited as Delphi study panelists. A modified three-round Delphi study approach (Warner, 2014) was used to collect data via online surveys, which were designed using the tailored design method of Dillman et al. (2014). In the first round, open-ended questions were sent to panelists, focusing on competencies related to conducting transdisciplinary evaluation. Responses from the first round were analyzed using the constant comparison thematic analysis method to identify themes. These themes formed the basis for formulating subsequent round two survey statements. In the second round, participants were presented with the identified thematic evaluation competencies related to transdisciplinary project evaluation. In the final round, participants were asked to express their agreement with the final categories derived from round two using a five-point Likert scale. The Delphi technique facilitated the development of a comprehensive list of competencies required by transdisciplinary evaluators in sustainability-related projects.

The fifth chapter is a comprehensive chapter that briefly revisits the research questions, salient findings, limitations of the study, theoretical contributions, implications of the research, recommendations for future research, and revisiting the researchers' positionality.

Researcher Positionality

I am a male researcher, born and raised in Punjab, India. I have lived mostly in Punjab, India, where agriculture is prominently practiced. Though my family is not engaged in agriculture as a business; however, being a part of the community, where the majority is engaged in agriculture, has influenced my thought process and interest significantly. The agricultural

fields and livestock are the first-place memories where my interest in agriculture began to sprout. The lifestyle of the farming communities, their agricultural practices, and their problems have always aroused my curiosity and kept me motivated to pursue a higher degree in agriculture.

Consequently, I studied for B.S. in Agriculture and M.S. in Extension Education in Punjab, India. Apart from my educational background, I have previously worked on a natural resource management-related project where most of the stakeholders were cereals, vegetables, and fruit growers. Working closely with farmers helped me understand certain aspects of the cultivation of crops, the use of agricultural inputs, socio-demographic factors, and their constraints in adopting the best management practices. These experiences were eye-opening and helped me identify their needs and constraints. There was also curiosity to understand who could help the farmers and in which ways. I was keenly interested to know how the farming communities could benefit from universities and allied institutions' educational, research, and outreach efforts. As I could study their needs and constraints, but I had no opportunity to put those findings in front of governmental officials and discuss the best ways of addressing them. Therefore, I wanted to work with broader groups of stakeholders and learn how the co-production of knowledge takes place. I wanted to learn how to develop knowledge systems that provide opportunities for broader stakeholders to initiate dialogues with the government to address their issues related to farming. Additionally, I was always interested in determining whether farmers benefited from the research, education, and outreach efforts. I did not have sufficient program development and evaluation skills to find these answers. The opportunity to learn and apply program development and evaluation skills is one of the greatest reasons to pursue graduate studies so that I can learn tools to develop co-production of knowledge to maximize the benefits for broader stakeholders, e.g., farmers belonging to varying social-economic conditions.

It is also acknowledged that agricultural scenarios in the United States of America (USA) and India are different. Therefore, I do not have much experience working with diverse

stakeholder groups other than farmers. I also do not understand their needs, expectations, and interests from the universities-based research and education. Therefore, my international student experience shaped my outsider view of agricultural systems in the USA. However, I view myself in the present research as an insider as I am in regular contact with the participants of Thriving Agriculture. In this case, my role is of an insider researcher because I have immersed myself sufficiently in current research activities and partially identified stakeholders' needs and expectations from this research.

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Chapter 2
Knowledge, Motivations, Advantages, and Challenges to Engage in Transdisciplinary Research

Abstract

The complex nature of sustainability challenges transcends the capabilities of any single discipline, underscoring the necessity for collaborative efforts among all stakeholders involved. The transdisciplinary research (TDR) approach is recognized for its potential to address such complexities. Despite the central role of the researchers in TDR, their positionality has yet to be well studied in TDR literature. A few studies have stressed the attitudes, motivations, and roles; however, the conceptual understanding of TDR and transdisciplinary researcher (TD researcher) still needs to be explored. To our best understanding, the connection between theory and application of TDR concepts within a single study has not been studied. Therefore, the present investigation aimed to connect the theoretical understanding with the researchers' motivations, advantages, and challenges while working on a TDR project. To achieve this aim, qualitative research was conducted between March and June 2024 using the Thriving Agriculture Project as a case study. This project is an ideal TDR project; therefore, the researchers, graduate students, and postdoctoral fellows currently working on the project were invited to participate in the research. Data were collected online, further recorded, transcribed, and analyzed following the standard procedures. Research findings revealed significant discrepancies in researchers' conceptual understanding of the concepts of TDR and TD researcher. The TDR is especially perceived as an interdisciplinary and multidisciplinary research approach, which is epistemologically different. We define TDR as a process that can address complex challenges by integrating diverse disciplines and perspectives of researchers and stakeholders by considering contextual factors. Further, the characteristics of TD researcher identified include problem-

solving, collaborations, integration of disciplines and stakeholders, integration of contextual factors, and personal drive to address complex issues. Research also revealed that the nature of complex challenges, opportunities for enhancing collaboration, research skills, and engagement with external stakeholders were initial motivations to engage in TDR projects. Motivated by such opportunities were actualized as almost identical advantages were received by the participants (e.g., improving knowledge and skillsets, professional outlook, collaborations across disciplines, institutions, and external stakeholders). However, the difficulty in understanding and managing the project, complex dynamics, finding their own positionality, time commitments, and logistical constraints were some of the challenges expressed by the participants. The research has implications for the researchers and stakeholders, indicating the need to train professionals to navigate the tensions arising from confusion, uncertainty, and associated challenges. Emphasis on training through strategic capacity-building programs is required to allow researchers to effectively work toward the needs of science and society and navigate such tensions. Support from funding agencies is needed to ensure that the scientific community and stakeholders are fully equipped to address the sustainability challenges.

Keywords: Transdisciplinary research, transdisciplinary researcher, motivations, stakeholders

Introduction

The wicked problems are inherently complex and involve varied interests, interconnected variables, unpredictable side effects, and often a lack of supportive data to fully understand the uncertainty embedded within these problems (Kirschke et al., 2022). Therefore, a comprehensive understanding of wicked problems, including their theoretical foundations, meanings, epistemological dimensions, and rhetorical implications, is essential (Lönngren & van Poeck, 2021). However, addressing wicked problems goes beyond just finding ultimate solutions; instead, it involves exploring and refining the approaches needed to address them (Alford & Head, 2017). To tackle the wickedness of problems, applying TDR has become increasingly prominent in the last ten years (see, Polk, 2015). Given the inherent complexity and uncertainty of wicked problems, a transdisciplinary research (TDR) approach is essential for developing practical solutions to contemporary challenges (Hirsch Hardon et al., 2018).

TDR is a specialized form of interdisciplinary research that integrates scientific and non-scientific knowledge to collaboratively address societal challenges through novel learning approaches, creating new governance structures, and establishing diverse partnerships (Cardona et al., 2024). The problem context is an essential factor in TDR that decides the suitability of research and its impacts on science and society (Gooding et al., 2022). The key to addressing complex challenges is developing knowledge that transcends specific disciplines (McGregor, 2004). Therefore, TDR is more suitable when the problem context is unclear, and issues have broader implications for people affected by these problems (Pohl & Hirsch, 2007). TDR is often synonymous with interdisciplinary and multidisciplinary research (Lawless et al., 2024). Epistemologically, multidisciplinary entails using disciplinary specific methodologies while the interdisciplinary research approach integrates shared framework that allows interconnection of

various disciplines to solve a common problem (Wickson et al., 2006). However, there are differences between interdisciplinary and transdisciplinary (Pohl et al., 2021). TDR is more effective than interdisciplinary or multidisciplinary research approaches (Gooding et al., 2022; Hansson & Polk, 2018). The scope of TDR ranges from global to individual levels (Klein, 2014). The TDR process evolves continuously to meet the current research needs and changing stakeholders' perspectives throughout the project (Wickson et al., 2006). Yet the literature lacks the standard methodology to effectively conduct TDR (Wickson et al., 2006). The stakeholder collaboration component differentiates TDR from other research approaches (Wickson et al., 2006). The research problems in TDR are 'in the world and actual', highlighting that those problems belong to real-world situations (Wickson et al., 2006, p. 1048). Given the wide-ranging applicability of TDR, it is suitable for addressing complex problems with unclear solutions, where no single source of knowledge or expertise can effectively address the broad implications for various stakeholders.

Considering the conceptual differences from other approaches, it is essential to establish a common grounding on TDR and its application across disciplines (Jahn & Keil, 2015; Lawless et al., 2024). In the early 2000s, transdisciplinary researchers were not widely recognized (Augsburg, 2014). A clear understanding of TDR's concepts, methods, and applications enables researchers to embrace the multifaceted nature of the TDR process. Researchers' positionality in the TDR context influences their perception of the problem context. It also shapes how they navigate processes, integrate stakeholders, develop impacts, and consider implications.
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Positioning in the TDR context requires an apparent vision of the researchers' role, expectations, and activities. Thus, understanding one's position, strengths, and weaknesses is imperative (Peters, 2013). The variables such as role of family background, gender, nationality, sexuality, and cultural background influences researchers' positionality in the research (Peters, 2013). Apart from this, Katoh et al. (2021) revealed that intrinsic and extrinsic motivation are linked to creativity and emphasized connecting intrinsic motivation to interest in the TDR. The motivation for TDR includes addressing societal problems and contributing to the advancement of the common good (Augsburg, 2014). Motivations to engage in the transdisciplinary could be extrinsic (e.g., rewards) or intrinsic (e.g., personal satisfaction by advancing scientific horizons). A key motivator for researchers to engage in TDR projects is the expectation of peer-reviewed publications, which are often seen as the primary 'product' of academic endeavors (Jaeger-Erben et al., 2018). In contrast, contributions to non-academic stakeholders, while valuable, are less recognized and rewarded. The lack of a standardized mechanism for evaluating the worth of practitioner-oriented publications further discourages researchers from engaging in and publishing these types of peer-reviewed articles (Jaeger-Erben et al., 2018).

Despite the scope of addressing complex problems, the TDR approach is perceived as challenging for various reasons, such as time, resources, patience, and interpersonal skills. The factors that deter researchers from engaging in TDR have been categorized into three broad categories: cross-disciplinary, individual, and systemic barriers (Mehta et al., 2024). For example, identifying a common focus area that aligns with the interest of diverse stakeholders concerned with scientific, societal, and policy (Jaeger-Erben et al., 2018; Rosendahl et al., 2015) and

adjusting, and adaptivity to changing work situations to achieve the project goals was found challenging (Cardona et al., 2024). From the funding perspective, TDR research proposals are expected to articulate clear research goals and methods. However, it isn't easy in practice due to the dynamic nature of the TDR process, where goals and methods evolve constantly through shared learning and the collaborative vision of stakeholders (Mattor et al., 2014). Engaging in the co-production process within the TDR is challenging due to the demands of time and resources. Additionally, co-production includes '*disciplines being hegemonic'* that might hinder the representation and over-representation of one discipline over the other disciplines (Peters, 2014, p. 189).

A recent review of TDR research paper discloses tension that requires careful consideration, for instance, expectation of results from funders and stakeholders and tensions arising between the completion of the activities as some activities take shorter time versus longer time. The long-term time commitment required for a project also leads to disengagement from the project (Jaeger-Erben et al., 2018). Additionally, networking with diverse stakeholders is a demanding task considering distinct styles of communication, which makes it challenging to connect and maintain relationships during early-career research (Jaeger-Erben et al., 2018). Along with the scientific and social perspective (Sellberg et al., 2021), it also includes the 'self' aspects of researchers to navigate through the various emotional regimes while engaging in TDR.

Recent research aimed to understand how researchers approach TDR and position themselves as a part of their research identity (Hakkarainen et al., 2023). It is important to distinguish whether the researchers identify themselves as sustainability researchers or researchers who do sustainability research. The point of interest here is the positionality of the researcher. Hakkarainen et al. (2023) outlined a critical difference between 'being' and 'doing' sustainability research. We argue that it is also equally indispensable to discern researchers’

perceptions of the TDR along with identity of TDR. Understanding of these aspects is important to clearly know the theoretical positioning of the researchers in the research, which sets the stage for gaining insights on the other aspects such as motivations, advantages, and disadvantages of TDR. Typically, the research has focused on the researchers' roles, skills, and motivations. More research is needed to report the transdisciplinary collaboration, barriers, and enablers for conducting successful TDR collaboration (Kaisler & Grill, 2021). The roles of the researchers are not standalone; they are dynamic and ever-changing (Bulten et al., 2021; Hilger et al., 2018; Wiek, 2007; Wittmayer & Schäpke, 2014). Prior research has attempted to study the perspectives of the individual researchers working on the TDR (Augsburg, 2014; Boyle et al., 2023; Fam et al., 2017). This research collectively investigates conceptual understanding and practical insights, which provides an opportunity to explore theoretical perspectives and practical aspects within a single study intended to envision if these are interlinked. The research broadly aims to answer the extent to which researchers' attributes (e.g., knowledge of TDR and TD researcher, motivations, advantages, and disadvantages) affect the success of TDR. The objectives of this paper were:

1. To determine the knowledge of concepts of TDR and TD researcher.
2. To determine the researchers' motivations to engage in TDR.
3. To understand the perceived advantages of being a part of TDR.
4. To understand the perceived disadvantages/constraints of being a part of TDR.

Methods

Study context

This case study uses the "Thriving Agricultural Systems in Urbanized Landscapes project" (*Thriving Agricultural Systems in Urbanized Landscapes*, n.d.) as a case for this

research. The Thriving Agriculture is a six-year project funded by the U. S. Department of Agriculture's National Institute of Food and Agriculture from 2019 to 2025. The project aims to promote economically and environmentally thriving agricultural systems located on the fringes of the urbanized landscapes in the Chesapeake Bay Watershed (CBW) in the next 25 years. The project is comprised of 16 research groups representing diverse expertise in stakeholder engagement, economic modeling, market analysis, watershed-scale nutrient management, and land use modeling. The project teams belonged to Penn State, the University of Maryland, George Washington, Ohio State, Utah State, Virginia Tech, and the Stroud Water Research Center. Along with research groups, the stakeholder advisory board represented by governmental and non-governmental partners contributes to the project's success. The project entails an ideal TDR environment as research groups and stakeholder groups collectively examine CBW's current and future situation. For regular knowledge sharing, online and offline meetings and workshops are conducted to share research findings, learn about field realities, and seek their feedback (*Thriving Agricultural Systems in Urbanized Landscapes*, n.d.).

Research design

A descriptive case research design was used for this research. A case study, as defined by Yin (2014), "*a empirical enquiry that investigates a contemporary phenomenon within real life context, especially when the boundaries between the phenomena and context are not clearly evident"* (p. 16). This design was particularly appropriate for Thriving Agriculture as it allows the study of a single case or investigation unit (Gerring, 2004) and advances knowledge on real-world complexity (Crowe et al., 2011, p.1). The Thriving Agriculture Project indicates the suitability of employing a descriptive case study to glean information about an issue of a

multifaceted nature (Yin, 2014). The research was motivated to study the lived experiences and reflections of the participants regarding various aspects of TDR within Thriving Agriculture.

Research participants

The population for the research comprised faculty members, graduate students, and postdoctoral fellows engaged in the Thriving Agriculture project. At the time of the study, there were 42 project members across 16 research teams. However, the two teams represented by lead researcher of this study and his faculty advisor were excluded from the research to avoid any potential biases. The faculty members ranged from assistant professors to full professors, while graduate students were enrolled at the master's and doctoral levels. The sample who provided data for this study included 15 faculty members and six students, with a gender composition of 13 males and eight females. There was no post-doctoral fellow in the sample.

Data collection and analysis

Data were collected using semi-structured interviews because we were interested in collecting rich data from participants about knowledge of TDR, the TD researcher, motivations, advantages, and disadvantages (Creswell & Poth, 2018). From the validity perspective, the interview protocol was sent to the reviewers for their feedback. A final interview protocol was developed based on suggestions and comments. The reviewers included the dissertation committee and external reviewers (e.g., environmental sustainability, environmental sociology, transdisciplinary research, environmental governance systems, community development, stakeholder engagement, ecosystem science, and management). The extant literature and research questions guided the interview questions. For example, a) *what does TDR mean to you?* b) *what*

comes to your mind when you hear the term TD researcher? c) *what were your initial motivations for joining the Thriving Agriculture Project?* d) *what have been the advantages/benefits to you being a part of the Thriving Agriculture Project?* Participants were emailed with an overview of the research and potential outcomes of the study. Upon willingness to participate, the participants were sent the consent forms and interview protocol in advance. Prior consent was obtained to record the interview and publish the findings in an aggregated form (Kaisler & Grill, 2021). The study was conducted following the guidelines of the Institutional Review Board of the Pennsylvania State University.

The interviews were conducted from March to June 2024. A total of 21 interviews were conducted, of which 19 were conducted via Zoom and two were in person. The interviews were recorded with the participants' prior permission. The recorded interviews were transcribed using Otter.ai software. Identifiers such as the names of researchers, stakeholders, and institutions were removed from the transcripts to ensure anonymity and maintain the confidentiality of the data. The three transcripts were randomly selected and read well to gain a preliminary understanding of the data.

The data were coded to answer the research questions and identify the patterns and emerging ideas (Yin, 2014). The coding process involved both inductive and deductive processes. The initial process involved developing codes closer to the participants' responses. The codes were collected to understand the participants' meanings, expressions, and intents, which later emerged, segregated, or deleted in the direction of answering the research questions and developing a code book. The codebook was continuously updated based on the identification of newer codes and revision of the prior codes. In this case, the second coder, who was not well-versed in the overall interviews and transcripts, was invited to code the data. Therefore, the understanding based on the transcripts was the only source of information. Both first and second

coders coded transcripts independently and discussed thoroughly codes, and discrepancies and developed a consensus on the codes (Cofie et al., 2022). In this process, the meaning of the excerpts, meanings, definitions of the codes, and language of the codes were discussed thoroughly. Each transcript was coded following the code book, and new codes were generated wherever needed throughout the coding process. Hence, a comprehensive list of the codes was developed.

Data analysis was conducted with the help of thematic analysis for this case study. This descriptive case study involves coding and themes (Saldaña, 2013). Initially, descriptive coding was used, which included open coding in the first round of coding (Corbin & Strauss, 2007). Open coding involves reading the transcripts, understanding the meaning, and reporting the codes close to what was expressed by the participants. In the second cycle, axial coding was employed, where initial codes were reviewed, combined, and developed into bigger codes to formulate the patterns, themes, and broader categories (Strauss & Corbin, 1998). This includes developing patterns from identical sets of codes and representing them in a story (Saldaňa, 2013). The information that may not contribute to answering the research questions was omitted. This is essential to identify emerging common patterns of the codes to synthesize in different themes (Creswell & Poth, 2018). Initially, open coding was done throughout, which was later compared to identify similar codes and then merged into developing themes (Braun & Clarke, 2006). In this process, the entire data was visited repeatedly to understand and ensure that the coding process was in the direction of answering the research questions. Thus, we immersed ourselves in the data to identify the meaning and patterns and ensure that the coding process was in the direction of answering the research question. Once all the transcripts were coded, the data was seen through a comprehensive lens to identify the long list of codes throughout the data set. This included combining various codes which convey the same meanings (Braun & Clarke, 2006).

Trustworthiness of the research

The trustworthiness of the research instruments was achieved by employing dependability, credibility, transferability, and confirmability (Lincoln & Guba, 1985). Credibility ensures the truthfulness of the findings, transferability enables the application of the research findings to other research scenarios, dependability allows the replication of findings, and confirmability confirms that findings are free from researchers' bias and prejudices and precisely reflect the participants' view (Lincoln & Guba, 1985). As both the researcher and participants were part of the same project, members checking was used to determine whether to verify events, facts, data, and interpretation (Lincoln & Guba, 1985). The transferability of findings was achieved by using thick descriptions. We used direct quotes and verbatims from the data to ensure the applicability of findings to other research contexts. Confirmability was achieved by reporting each stage critically. Confirmability was achieved by taking field notes, writing memos, and personal reflections. Audit trailing was done (Sandelowski, 1986) to ensure that future researchers can trace the decision-making process at various stages of the research. For the credibility of the findings, panel testing of the interview protocol was conducted to ensure all the questions were sufficiently covered.

Results

The research aimed to understand the positionality of researchers in TDR. The findings have been broadly classified into five sub-sections: knowledge of the concept of TDR; knowledge of TD researcher motivations for engaging in TDR, advantages of participating in TDR, and challenges faced while working in TDR.

1. Knowledge about the concept of TDR

While assessing the perception of the TDR, participants offered a diverse array of conceptual nuances related to the term TDR. The findings containing five themes based on data analysis were summarized in two ways. First, there was a notable degree of confusion and uncertainty about the term TDR. Secondly, participants tried to express TDR based on semantics, past experiences, prior knowledge, and its current application in research programs.

Challenges and confusion to explain TDR

It was observed that participants made considerable efforts to define and express their understanding of TDR. However, there was a lack of clear description, and confusion existed about the definition, use, and application of TDR. For instance, some participants mentioned that TDR is merely a different way of explaining interdisciplinary or multidisciplinary research, however, these are different approaches in theory and application. We learned from the participants that "*Transdisciplinary is just maybe the current buzzword. And, I have had in the past, I've been on teams where people were trying to differentiate between interdisciplinary and multidisciplinary. To me, they all mean the same thing."* [Participant 01].

Research application to address real-world complexity

Participants perceived TDR as a promising approach for addressing complex environmental and societal challenges. Most participants opined that TDR aims to address real-world challenges through joint problem analysis and considering alternative solutions. TDR was perceived as a process that aims to generate knowledge and outcomes that are applied in real

situations. It was learned from one of the participants *"we get a little more challenging, the further you get into a project because your ability to adapt to the next iteration diminishes a bit. But it's kept us very focused on applicability to sort of the real world, real people, real challenges."* [Participant 14].

Role of contextual factors

The participants opined that addressing real world complexity requires consideration of interconnected contextual factors, which included clarity of historical, policy, social, and environmental contexts, and their effects. They perceived that these factors have an influence on research practices and outcomes of the research. One participant quoted, "*I don't know if you would also count that as sociological because it is kind of humans as well. But you have to look to see the history of the site to see what you're working with in general."* [Participant 05].

Integration of diverse disciplines

The findings revealed a strong emphasis on participants' view of TDR that TDR allows integration of diverse perspectives and disciplines, which enables researchers to learn from each other's disciplines and use their models, methods, and practices. Moreover, the participants stressed the need for disciplinary integration, when the research problem may not be addressed using the tools of any single discipline. There was a significant focus on collaboration between disciplines working on common issues by leveraging the strengths of multiple disciplines. As one participant mentioned, *"co-learning between research, expertise and research units and disciplines, so that the research then just becomes richer, when different disciplines and research expertise understand a little bit better the disciplines of others."*

Integration of researchers and stakeholders

Participants emphasized that TDR includes joint effort of researcher and stakeholders in the research process. For example, participants mentioned that the combination of researchers from academic organizations and nonacademic organizations jointly explore the possibilities and opportunities of addressing the precedent issues. One of participants noted, *"I think, specifically working with stakeholders and policymakers and people in other disciplines to get different perspectives on what people care about what people value before deciding what the ultimate goal is."* [Participant 19].

Participants also mentioned stakeholders' contribution in the TDR process as a part of the transdisciplinary research. Various components such as potential inputs from stakeholders, style of communication with stakeholders, and co-designing the research were discussed. In addition, the different stages of stakeholder integration, informing and receiving feedback, and benefits of stakeholder participation were also some of key ideas reported.

To conclude, it appeared that participants perceived that TDR is a process of addressing complex challenges by integrating diverse disciplines and perspectives of researchers and stakeholders by acknowledging the role and influence of contextual factors.

***2.* Knowledge about the TD researcher**

This section expands on understanding participants' views of the identity of TD researcher and offers insights on various nuances related to TD researcher. We identified two strands of findings: Firstly, we report confusion and challenges in describing and conceptualizing the identity of TD researcher. Secondly, some expressions and ideas reported different components of TD researcher.

Challenges in conceptualizing TD researcher

The research aimed to gain insights into the definition of TD researcher. We reported significant ambiguity, lack of clarity, and uncertainty among the participants regarding the concept of TD researcher. Participants struggled to express what distinguishes TD researcher from other researchers. Some equated TD researcher with researchers who are involved in multidisciplinary or interdisciplinary research approaches. They emphasized that these terms are identical and interchangeable. One participant said that it is more just a TDR work than any research that specifies or is associated with TD researcher itself.

Problem-solving through applied research

A variety of expressions and responses were collected from participants who tried to explain who TD researcher is. Some participants interpret TD researcher as problem solvers through applied research methods. Participants believed that TDR's philosophy emphasizes its capacity for conducting direct, applied research, generating diverse solutions, and engaging in research with practical real-world applications. As one participant mentioned, "*I think that the way that is set up has been quite useful for the project, but also actually making sure that we are doing something that might be useful and usable on the ground*." [Participant 06].

Collaborations with external stakeholders

The participants defined a TD researcher is someone who is able to seek and build collaborations with a broad range of stakeholders outside academia. As one participant mentioned, *"transdisciplinary researcher I think of somebody who's engaging broadly both*

within the college across the university, and I would argue beyond the university walls." [Participant 10].

Collaborative across diverse disciplines

Participants also view TD researcher as someone who can work effectively across disciplines. The ability to understand and learn the interconnections among the disciplines and the application of such concepts and methods have been stressed upon. As one participant mentioned that TD researcher have, "*ability to straddle boundaries in different disciplines to get answers to questions that may not be possible within just their single disciplines.*" [Participant 19].

Expertise in diverse disciplines

Participants define the TD researcher as someone who has expertise in diverse disciplines. It was not very much a recurring theme but was reported in a few interviews only. As the participant mentioned, *"I think, the other thing that comes to mind that there are some academics that are talented in more than one discipline. I mean, for example, may have been trained in plant science, but over time acquire a lot of expertise in agricultural economics."* [Participant 17].

System and contextual understanding

Participants opined that a TD researcher's identity depends on understanding of contextual factors (e.g., social, historical). Moreover, the participants also opine that TD researcher has the ability to contextualize the information and can grasp the meaning and

interconnections of smaller components of researchers in relation to larger complex systems. One participant highlighted, *"But yeah for capstones, I could use the TDR or my multidisciplinary researcher but like in orders for in the field with these like, as working as a researcher and then depending on the cases they will be working in like in that system."* [Participant 07].

Personal motivation

Apart from the disciplinary, collaborative, and applied nature of TD researcher, the participants considered the personal motivations of researchers helping them form the TDR identity. The role of personal drive, curiosity, intentions, and willingness aid to create the TD researcher identity of the individuals. As remarked by one participant, "*where we have particular technical expertise and it takes a certain amount of intentionality to maintain the communication and focus on being transdisciplinary.*" [Participant 14].

In light of the results, the combination of various themes helped us define a TD researcher as somebody who can conduct applied research by fostering collaborations across different disciplines and with stakeholders, having a clear understanding of contextual factors, and personal drive to address complex issues.

3. Motivations for engaging in the TDR

This section encapsulates the key findings related to initial motivations of the researchers that led them to join the Thriving Agriculture Project, or TDR. The purpose of this investigation was to determine what motivates people to engage in addressing complex challenges and being a

part of a large team setting that aims to achieve grand objectives and address complex challenges. We identified seven motivation themes.

Addressing complex challenges for wider impact

Our findings revealed that one of the motivations for participants to engage in the Thriving Agriculture Project or TDR project was the opportunity to address long-standing sustainability issues, such as issues related to urbanizing landscapes in the Chesapeake Bay Watershed. Participants mentioned that these issues are long-standing and have long-term impacts and implications, which motivated them to engage in this project for a transformative change. One participant said, *"I've personally witnessed the challenges of trying to maintain productive and healthy agricultural systems, and agricultural communities in an urbanizing landscape. So, trying to tackle it, how to ensure that these ag systems remain viable and thriving in places like Pennsylvania and the Mid-Atlantic and the Chesapeake Bay watershed. That is a personal interest of mine."* [Participant 12].

Collaborative research and network opportunities

Participants mentioned that opportunities for research collaboration and network opportunities were some of the motivations. By nature, TDR projects, e.g., Thriving Agriculture, have multi-disciplinary and inter-institutional partnerships, which offer significant scope to connect with and expand professional networks with colleagues from different institutions who share similar research interests. One participant mentioned, *"I think my motivations were as I really like people. So, the opportunity to network outside of the University of [place] to other institutions and also, we do something to work in the Chesapeake Bay to learn about what's going on in [place] and [place] on a regular basis.*" [Participant 02].

Alignment with and advancement of research skills

Participants mentioned that the nature of the TDR projects, e.g., Thriving Agriculture Project aligned well with their current research areas and interests. Therefore, it was an opportunity to conduct new experiments and expand existing research expertise. One participant highlighted, *"My motivation was to move beyond a lot of the field scale work that I was doing to try and understand if across the bay, scan of what really matters for nutrient cycling."* [Participant 8]. Another participant mentioned, *"I was really excited about that opportunity to work with a larger team on an issue which, is dear to me, because I've been working on it. So that it was it was really exciting to me."* [Participant 07].

Context, vision and outcomes of the project

The contextual components of the project, such as components of research, futuristic approach, scale of operations, and contextual understanding of the complexity and ground realities of issues, were some of the motivators for engaging in TDR projects, i.e., the Thriving Agriculture Project. Participants mentioned that potential outcomes of the project, for instance, learning about the TDR outcomes and feasibility of applying evaluation on the TDR were some of the driving forces. One of the participants highlighted, "*So, I was very excited about that part to work on a project, which at this scale, this is my largest project in the in findings, on the front side*." [Participant 07].

External stakeholder engagement

The opportunity to collaborate with various external stakeholders (i.e., non-academic) was motivating to participants. Participants emphasized the importance of engaging with stakeholders for feedback and collaboration. They noted that such interactions help expand their

networks for conducting in-depth research, exchanging ideas, and gathering valuable insights. One of the participants elicited, "*that was definitely part of the interest. I think [T20] and I both really recognize the importance of having this stakeholder advisory board and having a really robust discussion back and forth with the farmers and ag sectors about the research so that both ways we were really tapping into their expertise*" [Participant 14].

Professional growth

Apart from research and collaboration opportunities, the participants mentioned that TDR projects have had potential in terms of meeting the needs of tenue requirements, publishing research articles, early career collaborations, and securing large-scale funding, especially hiring graduate students for research. Participants view these opportunities as incremental to career promotion and establishment. One participant mentioned, "*I was a very new Assistant Professor at that point. You have got to meet all these expectations for getting tenure and things like that."* [Participant 01] and, one of participants also mentioned, "*It was also sort of be a great resource to help drive that research forward with some funding for students and research costs and things like that. So, I think those were the two motivators*." [Participant 01].

Engagement with diverse disciplines

The niche area of the Thriving Agriculture Project, i.e., promoting agricultural sustainability in the urbanized landscapes in the Chesapeake Bay Watershed is broad and encapsulates multiple perspectives and disciplinary knowledge. Therefore, participants view these opportunities rewarding to learn interconnections of agriculture with populations and apply disciplinary knowledge to address the common problem. One participant highlighted, "*That was the place that I had experienced the most. There is also a lot of soil science involved with it,*

which is the degree that I'm trying to achieve with my masters. That was pretty interesting to me. I thought it was super interesting. I don't know if you've seen our plot design, but all the different moving parts was interesting to see how it's all going to come together, and how it all be useful in the end." [Participant 05].

4. Advantages of participating in the TDR

It was interesting to explore the benefits of TDR engagement to researchers working on the Thriving Agriculture Project. The major themes that emerged in this section included: advancing scientific knowledge and skills horizons; professional development and growth; research outputs, impacts, and implications; resource and institutional support; understanding of other disciplines; and broadening networking and collaboration opportunities.

Advancing scientific knowledge and skills horizons

The participants expressed that engaging in the Thriving Agriculture Project helped them advance their research skills, research outcomes, broadened knowledge horizons, and offered them ample opportunities for professional growth and career promotion. The participants feel that engagement in TDR helped them explore new areas of research, for instance, economic modeling specifically or natural resource management broadly. The continuous engagement in the project facilitated improvement in the knowledge as they were able to brainstorm new research ideas, expand research work to different scales, integrate different perspectives, enhance knowledge of own and other disciplines and their interconnections, and learn in large team settings. One of the participants mentioned, "*Well, I think, it's definitely helped us advance our research. It's definitely advanced our research…. But it's advanced within our discipline."* [Participant 01].

Professional development and career growth

As mentioned in the method section, the Thriving Agriculture Project is a large grant (i.e., $9 million). Some participants asserted that joining the Thriving Agriculture Project helped them advance careers (e.g., getting tenure), improve project management skills, professional development and opportunities to mentor and supervise graduate students. Moreover, the project itself offers several opportunities to improve project management skills and attend conferences that have a positive impact on the professional outlook of participants. One of the participants highlighted, "*I'm sure, it helped me get tenure that I expect to get in a couple months, hopefully, I'll get that'll be approved… I ended up serving on a graduate students committee, who was working on the project from [place] … so I think that was good, it helped me stay in touch with some closer touch with some of my colleagues in [place]."* [Participant 01]. More specifically, one of the participants said, "*Well, the project management skills certainly have improved*." [Participant 17].

Research outputs, impacts, and implications

The findings also emphasized the benefits of the TDR engagement on the improvement of quality and quantity of the outputs, outcomes, and impacts. Participants reported improvement in research productivity and outcomes, for example, they were able to produce research articles, work effectively as a collaborator, and envision a great potential of converting the current research into future TDR projects. The participants also mentioned that it is meritorious to see the application of data on the ground and the opportunity to a make difference through Thriving Agriculture Project. One participant mentioned that, *"and also on the publication side, we are still starting to see some of the products coming from the work so."* [Participants 07]. More specifically, one of the participants expressed that *"I got two papers from these."* [Participant 13].

Resource and institutional support

The availability of the support in terms of funding, institutional, and other resources benefited the researchers in multiple ways. To illustrate further, the participants felt that funding support from the grant was instrumental in funding the graduate students, exposing them to conferences, hiring new staff, and accessing the data. Overall, the availability of the funding facilitated running their research operations effectively. One of the participants said, *"There's been a lot of funds that have helped support students and postdocs and research expenses and things like that."* [Participant 01]. Additionally, it was learnt from a participant, "*also funding for travel conference travel. That has been helpful. It has funded my graduate education for the most part. I think that's an advantage."* [Participant 03].

Understanding of other disciplines

The Thriving Agriculture Project is a diverse, broad, and multi-institutional project. There are several interconnections among the disciplines, methods, and approaches to achieve overall goals of the project. This led participants to interact with other researchers working in different disciplines, learning their interconnections, and applying to address problems. "*I joined the task team [xx], I knew so little about agriculture practice and such. [T02] helped me a lot in terms of detailed agricultural practice works in the economics field that helps a lot. I led to all these presentations from other task team about cover crops about nutrient runoff, how to reduce. For example, from [T14]. So those things really help understand how to incorporate other fields with economics."* [Participant 09].

Broadening networking and collaboration opportunities

Participants emphasized that Thriving Agriculture Project offered them opportunities to connect with broad stakeholders, and they perceived to extend such collaboration beyond the project life for exploring newer areas of research. These opportunities include working across various institutions and disciplines, identifying key stakeholders, fostering new relationships, and consulting on research problems. One of the participants remarked, "*The biggest advantage has been creating a larger collaborative network of researchers and stakeholders. And it is really a nice mix of, we've been working on this for a couple of years."* [Participant 04].

5. Challenges faced while working on TDR projects

Despite the benefits of TDR engagement, the participants expressed a wide array of challenges related to the nature of the project, research processes, time, understanding their positionality, and career promotion and logistics. The significant themes related to challenges reported in the context of TDR were a) intra and interdisciplinary collaboration challenges, b) logistical constraints, c) understanding own positionality in the overall project, d) understanding and managing complex project, e) engagement and feedback integration, f) realizing TDR outcomes, g) time management, and h) aligning student priorities and TDR goals, and i) accessing and sharing of data.

Intra and interdisciplinary collaboration challenges

Participants expressed concerns related to the clarity of team composition. Some participants also expressed concerns related to a lack of team commitment. For example, some participants remarked that they are yet unaware of the roles and responsibilities of other teams, and how different teams combine to achieve a broad goal. The participants were struggling to

identify the interconnections of their tasks with other teams, *"It is hard sometimes for me to understand how this came to be and why all these researchers are together, and what the objectives really are."* [Participant 12].

Logistical constraints

The Thriving Agriculture Project is multi-institutional, the participants find it challenging to be physically present at all the workshops and meetings constrained by geographic distance. Thus, they feel constrained to miss out on the opportunity to interact with stakeholders and learn the current state of the art of affairs on the ground. One participant mentioned, "*The hardest part for me in this particular project is we are housed at [place] I don't deal with [T32] and [T31] on a daily basis. A little bit of I feel like we're out there alone*" [Participant 02]. Additionally, another participant mentioned, *"I would say being geographically sort of separate from the Chesapeake Bay watershed where everything's happening, has definitely not been to our advantage."* [Participant 06].

Understanding one's own positionality in the overall project.

The participants experienced difficulty in understanding their positionality in the project. The participants expressed that they grapple how their individual tasks are befitting into the large aims of the project. In addition, there was difficulty in staying focused on different project tasks. One participant mentioned, *"that's probably big at the beginning. We are also bounded by our component to this part, so it is a little different, just topic wise, for our position part in this research. So we are kind of a little bit unless we, unless we feel like open up a whole new topics. Otherwise, I feel like that's naturally, we're naturally bounded here."* [Participant 06].

Understanding and managing the complex project

By nature, the Thriving Agriculture Project is an extensive research project. Therefore, participants struggle to remain updated with other team members' research progress. They mentioned that it is difficult for them to stay updated with the accomplishments of others and understand the overall objectives of project. Regarding the size, some teams being relatively smaller in size also fail to find how their research resonates with others in larger project context, *"I think one of the disadvantages is that having too many people sometimes you cannot give them like to every person a time to present or be too active."* [Participant 15].

Engagement and feedback integration

Some participants also mentioned that it is difficult to align the research objectives with needs of the stakeholders. They also felt difficulty in connecting with stakeholders and uncertainty about using stakeholders' feedback. *"there were sometimes at which we ended up a bit circular in our discussion of the scenarios and sort of how we were going to integrate feedback from the stakeholders."* [Participant 14].

Realizing TDR outcomes

Participants also stressed that realizing the TDR outcomes takes a long time. The nature of the TDR process and the time to report the outcomes require committed efforts and a long time to reach fruition. One of the participants highlighted, *"If I were just doing the nitrogen cycling stuff, I would probably have several publications in these three or four years. Our team has been moving just fine. You have to kind of accept that products are going to be slow."*[Participant 08].

Time management

Time management was the most difficulty experienced by the participants. Participants experienced difficulty in time management in terms of following the presentations during the meetings, reporting periodic updates, and managing time for various meetings in the project. One participant said that it requires a long time to attain the TD researcher identity. Apart from time management, participants also expressed that TDR publications require relatively longer time for preparation and publishing. As one participant expressed, *"With any transdisciplinary project, it takes a very long time."* [Participant 08].

Aligning student priorities and TDR goals

Other concerns were related to limited opportunities and engagement in the context of students' participation. The participants mentioned that students are hired for research projects for a shorter period instead of time needed for results to be visible. Moreover, participants also emphasized that all the students are not always interested in taking up the TDR project, especially for their dissertation, *"And not all of them have gotten, they've had other priorities to like to get their dissertation done. Totally fair, as opposed to finishing what we needed for the scenario work."*[Participant 20]

Accessing and sharing data

This was a minor difficulty expressed by the participants that in large projects, sharing confidential data and gaining access to data is difficult. One of the participants mentioned, *"In that, you want to. Interesting to see from a researcher point of view, and it's sometimes hard to*

communicate to others without being able to disclose brand names or any identifying brand information." [Participant 11].

Discussion

To understand the positionality of researchers in TDR, the research provided different facets related to conceptual understanding of TDR and TD researcher, motivations, advantages, and challenges associated with it. Our research aimed to contribute to the scientific literature of TDR by offering insights into conceptual clarity of the researchers regarding TDR and identity of the TD researcher.

The findings regarding the conceptual clarity of TDR and TD researcher are two-fold. It was reported that TDR and TD researcher is viewed identical with interdisciplinary and multidisciplinary research approaches. There is evidence of a lack of clarity of interpretation of TDR, and further calls for clarity on its meaning (Sakao & Brambila-Macias, 2017). Guided by the observations during the interviews, participants struggled to articulate confidently the TDR and TD researcher. Another observation of participants' understanding of concepts was the integration of diverse disciplines and perspectives, that is, a partial explanation of the transdisciplinary but more about defining interdisciplinary and multidisciplinary research approaches. It was found that explanations resonated majorly with interdisciplinary research approaches than TDR (Klein et al., 2010; Pohl & Hirsch Hardon, 2007). There is difference between the interdisciplinary and TDR as the interdisciplinary approach is relatively less collaborative and lacks shared identification of problems and data analysis methods (Harris et al., 2008).

However, the integration and blurring the disciplinary boundaries is required for developing innovative solutions to address complex challenges in TDR (Wickosn et al., 2006).

Most of the participants did not mention the participation of non-academic stakeholders in their research process, which is considered an important and distinguishing component of the TDR from other research approaches. The societal relevance was somewhat blurred in the definitions outlined by participants, which is, on the contrary, an important concept (Zscheischler et al., 2018). When answering the TDR, some participants took some time to brainstorm their answers. There was an apparent indication of the initial struggle to coherently present their ideas (Zscheischler et al., 2018). One of the recent studies informed that researchers engaged in sustainability-related research did not view themselves as sustainability researchers. The study outlined the difference between 'doing' and 'being' the sustainability researcher (Hakkarainen et al., 2023). The clarity about the TDR approach further helps explain the methods it includes (Sakao & Brambila-Macias, 2017) because the perception of the term TDR affects the farming of problems and ways to address them. Despite confusion and difficulty, the study finds strengths of TDR (Marg & Theiler, 2023), which outlines various facets of TDR, such as addressing complex challenges and developing new methods and interdisciplinary use of the methods. The lack of clarity could be understood in terms of participants' composition. In our study, there were eight graduate students, who might not be aware of this TDR and TD researcher term and/or have not been involved in TDR-based projects. They were probably engaged and learning about the TDR for the first time. These factors might have been the factors behind the confusion and uncertainty about the terms TDR and TD researcher. Even the faculty members bring diverse expertise in different disciplines but lack direct experience with TDR. These situations might have affected the view of TDR and TD researcher above and beyond their capability. Primarily, confusion and uncertainty for the TD researcher existed; the study identified key attributes related to problem-solving, external collaborations, diverse disciplines, and contextual factors. Social impacts were sort of missing components in their explanations.

Further research is needed to better articulate the identity of researchers within the context of TDR. It is certainly a critical and herculean task to define the identity of a TD researcher versus who does TDR. However, some clarity and distinction about this is different is needed and would suffice to build consensus based on the roles, responsibilities, expectations, and contextual factors. Measuring the effectiveness of a researcher in a research context would help determine specific opportunities and challenges while being a part of TDR.

In the case of motivations, we observed that the complex nature of problems, improving research skills, collaborations, the scope of the project, the scope for learning 'out of disciplinary' perspectives, and career growth are the driving forces for the participants. Some other motivations were solving real-world problems, looking beyond the disciplines, and working at complex issues in the case of inter- and transdisciplinary research (Guimarães et al., 2019). A closer glimpse at motivations and advantages, there is a considerable degree of overlap. Practically, participants' initial motivations have been translated into benefits. Nonetheless, the assumption needs to be verified through follow-up studies.

Despite the advantages, there are certain constraints expressed by study participants, such as understanding their positionality and connections with other teams. Here, the Thriving Agriculture Project research team is located over multiple institutions and involves multiple stakeholders from governmental and non-governmental organizations, who have different viewpoints, expertise, and interests towards the issues. That limits the capacity of the researchers to remain updated and understand the intersectionality of their work with others. Even the teams whose research commitments are relatively lesser than other teams in project don't find a suitable tradeoff of their time with the participation in every project activity (e.g., workshops or Zoom meetings). While participants appreciated the project's size and scale, they also identified challenges. The interdependent nature of tasks often led to delays in outputs, and it was difficult

for individuals to grasp the overall project scope and their specific roles and responsibilities. It was observed that understanding one's own position and managing a complex project were some of the prominent challenges. Indeed, these could affect the positionality of the researchers within the TDR. Such difficulty might affect one's position, performance, and connection with other academic and non-academic stakeholders, which could eventually undermine the potential of TDR. Despite the motivations, the participants were constrained by difficulty in understanding the size of the project, interrelationships of the teams, their contribution in the larger picture of project, and remaining updated on project. Such challenges are associated with the nature of the TDR, thereby highlighting the skill developments to navigate such tensions arising from lack of clarity of TDR environments.

Unquestionably, the TDR is large, complex, and multi-dimensional in nature and requires a significant amount of time for research and stakeholder engagement. Our participants mentioned that it is challenging to devote time, especially for one project and other commitments such as other research projects, students' research, meeting deadlines, and attending meetings or workshops organized at various locations. This also discovered the pressure to develop societal output (Rogga & Zscheischler, 2021) and integrate the stakeholders' perspectives in the research (Lawrence et al. 2022).

Theoretical contribution

The study advanced an understanding of theoretical knowledge gaps and their impact on practice of TDR. For instance, there is a definite convergence between the lack of conceptual clarity and challenges faced in TDR (e.g., lack of understanding own positionality). The research informed us that a lack of theoretical guidance could impact the application of the research in an effective manner, which may cause consequences for the researcher (e.g., frustrations,

disengagement) or the research itself (e.g., underutilization of TDR's benefits), or stakeholders (e.g., lack of translating the findings to inform policy, disinterest, or disengagement). Previous research has examined the difference between 'doing' and 'being' a sustainability researcher (Hakkarainen et al., 2023). Our research aimed to understand the identity of the TD researcher and identified key elements (e.g., problem solver, collaborative, contextually aware, and intrinsically motivated). Following this, the current research set the stage for future investigations to identify and confirm the identity of a TD researcher. The research has theoretical and methodological implications in terms of collecting parameters of TD researchers' identity as well as building consensus using proven methods, e.g., the Delphi study (Dalkey & Helmer, 1963; Dalkey, 1972).

Limitations of the research

The current study has certain limitations that need to be acknowledged. Firstly, the findings rely on a small sample size taken from a single case study of an individual project, which restricts the generalizability of research findings to wider contexts. However, a study involving a broader set of stakeholders and researchers would be appropriate (Thompson et al., 2017). Secondly, the findings are based only on the qualitative research design and are limited by any statistical analysis (Tobias et al., 2019). Thirdly, the findings have been reported at one time of reference, and changes that have occurred over time are not reported (Katoh et al., 2021). Fourth, the data for this research has been collected in conjunction with another research study (chapter III), and the results may have been affected by research fatigue to some extent. However, the population for the sample was small, so it was unlikely to seek their availability for the second time. The findings also confirmed our hypothesis of their time constraint. Fifth, this research only aims to investigate conceptual knowledge, motivations, advantages, and challenges. Further,

research may also include attitudes and aspirations to advance the understanding of researchers' positionality.

Implications of the research

The findings have specific implications for the researchers and a variety of stakeholders. In the case of the researchers, the findings are relevant for the researchers who are faculty or graduate students. It is essential to pay attention to the fundamental understanding of the core concepts of the TDR and other operational aspects such as motivations, advantages, and challenges. A clear understanding of TDR concepts and applications can ensure the researchers' confidence and effectiveness in research. The research presents practical implications for researchers to consider the opportunities that TDR offers and how being a part of these projects can benefit at various levels (i.e., personal motivations, career advancements, addressing real-world complexity, integrating diverse disciplines and stakeholders).

The findings also spark the need for promoting TDR discussions in academic learning. University administrators can play a role in designing and supporting learning frameworks that allow regular training and educational programs. Such educational programs have the potential to build the identity of sustainability researcher (Hakkarainen et al., 2023). These initiatives could enhance learning about TDR concepts, application and constraints faced at various stages addressing complex problems. To enhance uptake of TDR by the research community, incentivizing the TDR in promotion and career development schemes could be useful. This is needed, for example, stakeholder identification, involvement and sustained collaboration require rigorous efforts, and pushing boundaries beyond university settings. Maintaining these partnerships requires continuous effort, yet the value of such interactions is not always immediately visible or measurable. There needs to have some quantifying measures that could

help decide the value of such interactions in the scientific discourse. Inclusion and incentivizing such efforts will encourage the community of researchers to expand their disciplinary boundaries and collaborate across disciplines and stakeholders to address the complex societal and environmental challenges.

The confusion and uncertainty about TDR affect the positionality of the researcher and the applicability of TDR in addressing the problems. This directly impacts understanding the research context, shaping research questions, adopting research processes, and envisioning research impacts for science and society. Apart from the lack of clarity about the TDR, a close glimpse of the constraints, for example, understanding and managing the TDR projects, and the lack of identifying own positionality also confirms the findings about the lack of surety of TDR contexts. This highlights the need to train professionals to navigate the tensions arising from a need for clarity and certainty in implementing research projects. There is a need to emphasize the training required for TDR (Boyle et al., 2023; Lawrence et al., 2022). Funding agencies may consider these aspects to ensure that researchers have the skills, resources, and mindsets to engage in the research. Secondly, acknowledging the discrepancy in researchers' knowledge, it needs to be clarified 'how much' uncertainty exists in the researchers' understanding. Therefore, this qualitative study seeks to initiate dialogue on quantifying uncertainty, paving the way for more rigorous assessment and informed decision-making. Thirdly, the role of researchers in TDR is not only limited to conducting research but also includes integrating with researchers and stakeholders. If the researchers are not well situated in the TDR contexts, it is likely not to fully utilize the scope of stakeholder engagement; instead, it might provide dissatisfying experiences. This could impact vision, use, and future collaborations if the stakeholder engagement fails to produce desirable outcomes. For instance, the researchers mentioned difficulty in integrating the stakeholder feedback. This could be understood as a communication barrier, especially a

translational gap in research. Therefore, educational training and skill development are needed to foster collaborative research environments and fill these gaps. Support from funding agencies (e.g., USDA NIFA) to ensure that the scientific community and stakeholders can collaborate to address is needed.

Future recommendations

Future research could use longitudinal research to document the changes in knowledge, motivations, advantages, and challenges the researchers face during the various research stages. Future research could also use a mixed-method data collection approach to gain in-depth insights (Zscheischler et al., 2018). Future studies could include socio-demographic variables and understand the interlinkage of socio-demographic variables with other variables. Information on the background of the participants would be helpful (Thompson et al., 2017). Such analysis will likely help present a quantitative picture and draw casual interferences. Our findings were limited to researchers' perspectives only. Nonetheless, future studies may include perspectives of stakeholders about TDR aspects, motivations, advantages, and challenges. Data from the combined analysis of the scientist and stakeholders' perspectives would help crystalline expectations and actions for both parties (Thompson et al., 2017). It will likely be helpful if a research study solely focusing on graduate students working on the TDR is conducted. These studies will help understand young researchers' current positionality and aspirations to engage in TDR in the future. Considering tensions reported in challenges, it will be helpful to report the positionality of the researchers through psychological variables (e.g., satisfaction, aspirations, and motivations); this could be achieved by adapting or developing standardized psychological scales.

Conclusion

The study aimed to determine the positionality of the researchers in the TDR. The research findings have presented various facets, such as conceptual grounding of the transdisciplinary research (TDR) and TD researcher among researchers and analysis of their motivations, advantages, and challenges in TDR. The research showed significant confusion around the definitions of the TDR and TD researcher. The motivations to engage in the TDR were addressing complex challenges, collaboration and networking opportunities, opportunities for expanding research skills, external stakeholder engagement, and professional growth. Moreover, the researchers benefitted by opportunities to advance scientific skills, professional support, institutional support, and collaborations. Despite advantages, understanding the complex nature of the project, managing time, accessing, and realizing TDR-based outcomes, and intra and interdisciplinary collaborations were some of the challenges faced by the researchers. The research adds to TDR scholarship by starting the discussion around the identity of TD researcher. The research also uncovers motivations, advantages, and barriers, understanding of TDR which is helpful to attract the researchers to work outside of their academic silos on issues that have both scientific and societal relevance. Future longitudinal studies could be instrumental in measuring the motivations, advantages, and barriers so that these could be addressed. The single case study may have limitations in diving deeper due to time, resources, and doctoral research study. However, it sets the stage for extensive studies to report the different behavioral aspects associated with the positionality of the researcher engaged in TDR

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Appendix A: Interview Protocol

We appreciate your willingness to support our research, which aims to understand the extent to which researchers' attributes (knowledge, skills, and motivations) affect the success of Transdisciplinary Research, especially in the Thriving Agriculture Project, Your participation is fully voluntary. Kindly feel free to stop me if you have any questions/concerns or do not want to answer any of the questions. I will read the informed consent form and appreciate your verbal consent before I start this interview. Upon agreement to informed verbal consent, I would like to record the interview if that is okay with you.

Knowledge of transdisciplinary research

The term Transdisciplinary Research is increasingly used these days in the calls for the projects, conferences, meetings, etc.

1. What does Transdisciplinary Research mean to you?

    a. What is Transdisciplinary Research? What does it include (or exclude)? How is thisapproach suitable for the Thriving Agriculture project?

2. What comes to your mind when you hear the term ‘Transdisciplinary Researcher’?
    a. Do you identify yourself as a transdisciplinary researcher? Please elaborate on why orwhy not.
        i. *If yes, move to question no. 04.*
        ii. *If no, move to question no. 05.*

Skills for Transdisciplinary Research

3. Why do you participate in complex projects like the Thriving Agriculture Project? What transdisciplinary skills, methods, and techniques do you bring to this research?

4. Based on your experience in the Thriving Agriculture Project, what skills, methods, and techniques do you want to learn further to engage in future Transdisciplinary Research collaborations?

5. What skills, methods and techniques have you observed others contributing to the Thriving Agriculture Project?

Motivations for the Transdisciplinary Research

6. Kindly discuss how you have come to be involved in the Thriving Agriculture project?
    a. What were your initial motivations to join the Thriving Agriculture Project?
    b. Are there any specific examples/incidents from Thriving Agriculture project that keepyou motivated to work on this project?

7. What have been the advantages/benefits to you being a part of the Thriving AgricultureProject?

8. What have been the disadvantages/difficulties to you being a part of the Thriving AgricultureProject?

a. Kindly share how these constraints were addressed?

Chapter 3
Scientists' Perceptions of Stakeholder Engagement and Knowledge Co-Production in Transdisciplinary Research

Abstract

There is growing interest in sustainability science research to respond to the complex environmental, societal, and public health challenges. This necessitates researchers and stakeholders to develop innovative and applicable solutions. For this, stakeholder participation and co-production of knowledge are increasingly desirable and employed in various capacities and contexts. Despite the existence of several frameworks and methods available, the research on the conceptual understanding of researchers about stakeholder participation and co-production is not exhaustive. To the best of our understanding, studies that investigate conceptual understanding followed by applying these concepts are lacking. The current study was conducted to address these research gaps and offer firsthand empirical findings. The research investigated conceptual understanding and reported the application and benefits of stakeholder participation and the co-production of knowledge. The qualitative research was conducted between March and June 2024 using a case study of the Thriving Agriculture Project. The sample for the research comprised 13 faculty members, and 08 graduate students currently working on the project. Data were collected by conducting one to one interviews (19 on Zoom and 2 in-person), which were recorded, transcribed, and analyzed. The results revealed a significant amount of uncertainty and confusion about concepts of stakeholder participation and co-production of knowledge processes. Stakeholder participation was understood as an active and iterative collaborative process aimed at supporting the researchers with current happenings outside the academic silos. In the Thriving Agriculture Project, the stakeholders familiarize researchers with ground-level issues, track project progress, refine the research process, share outcomes, and seek feedback. We also reported that stakeholder participation provided a satisfying experience to researchers yet there

were some instances of dissatisfaction expressed. In future, mostly researchers see their collaborations positively, except in some cases, they may discontinue or are conditional to engage based on availability of resources, stakeholders' interests in future projects, location, and scope of the project. Additionally, participants expressed that the co-production of knowledge prepared them to be accountable to the needs of stakeholders, expand research horizons, and stakeholder engagement, while the co-production was perceived to be beneficial for the stakeholders in terms of their enhanced access to scientific information, awareness of the latest research issues, and networking opportunities. Overall, the knowledge gap, i.e., lack of clarity and certainty about the stakeholder participation and co-production, draws attention to promote TDR education, for which the role of the funding agency, institutional support, and capacity building is instrumental to equip researchers with essential skills and knowledge of TDR to address the complex challenges.

Keywords: stakeholder participation, co-production of knowledge, conceptual clarity, transdisciplinary research

Introduction

The contestation and impacts of environmental and social problems require varied perspectives and expertise from disciplines and stakeholders to address them. Such problems are multidimensional and complex, where single disciplinary actions are insufficient. In this case, there is a growing demand for approaches to overcome the inherent limitations of a single discipline (Mehta et al., 2024; Zscheischler & Rogga, 2015). Thus, transdisciplinary research (TDR) extends possibilities to integrate knowledge from diverse disciplines and stakeholders for developing practical solutions (Hansson & Polk, 2018; Jahn et al., 2012; Lang et al., 2012; Mehta et al., 2024). The active inclusion of stakeholders and focus on complex problems distinguishes TDR from other research approaches (Woltersdorf et al., 2019). Rather than solely a theoretical, methodological, or institutional endeavor, TDR focuses on the practice aspect, i.e., how research is conducted (Jahn et al., 2012). Key characteristics of TDR include a) theoretical unity of knowledge, b) collaboration among different disciplinary experts, c) inclusion of non-academic stakeholders, d) focus on complex problems, e) focus on real-world problems, f) improvement in the quality-of-life and f) reflexivity (Knapp et al., 2019; Lawrence et al., 2022). Generally, stakeholders are individuals with relevant interests and capacity to contribute knowledge to research (Lemos et al., 2018). They are vested in policies and societal changes anticipated from the research (Knaggård et al., 2019). In TDR, the role of the stakeholders in identifying issues, defining research problems, and offering solutions to societal challenges is recognized in the co-production of knowledge (Lemos & Morehouse, 2005; Lemos et al., 2018; Norström et al., 2020). Thus, the application of knowledge for science and practice is central to the TDR goal (Nowotny et al., 2013). This study analyzes how researchers working in the TDR settings conceptualize stakeholder participation and co-production of knowledge and the extent to which these concepts are applied to address the agricultural sustainability challenges of urbanized landscapes in the Chesapeake Bay Watershed (i.e., using the Thriving Agriculture Project as a case study).

Overview of stakeholder participation and co-production of knowledge

Stakeholders are the backbone of TDR action and add social values to scientific research. The scientific expertise of the stakeholders is imperative as it directly influences their ability to apply the scientific findings for the benefit of the public good (O'Connor et al., 2019). Stakeholders have the potential to contribute at various stages of the project to foster shared learning (Bergmann et al., 2012; Bieluch et al., 2017; Jahn et al., 2012; Lang et al., 2012). Engaging stakeholders early is vital for understanding their local contexts, values, and priorities. Stakeholders could be informed about the context and methodology of the research to address the challenges related to TDR (Nagy et al., 2020). It is also important to identify promising degrees of stakeholder interactions to ensure that time, resources, and skills are responsibly used, and this also reduces the likelihood of failures caused by friction among collaborators and participation fatigue (Schneider & Buser, 2018). Effective stakeholder interaction enhances research accessibility and impact. Hence, the researchers need to understand the "why" of stakeholder interaction before considering "when" and "how" for systematic engagement (Knaggård et al., 2019). Thus, stakeholders could improve the quality of research at various project stages by helping researchers use local contextual information to devise research processes and decide priorities.

Co-production of knowledge is an important benefit of stakeholders' inclusion in the research. The co-production process emphasizes fostering strong relationships with the stakeholders, jointly exploring solutions, collaboratively implementing actions, assessing impacts (Norström et al., 2020), and developing equitable relationships (Yua et al., 2022). Norström et al. (2020) define the co-production process as an "*iterative and collaborative process involving diverse types of expertise, knowledge and actors to produce context-specific knowledge and pathways towards a sustainable future"* (p.183). Van der Hel (2016) emphasized that the co-production of knowledge through stakeholder interaction relies on accountability, impact, and

humility. Accountability refers to the need to be responsive to society's expectations and needs by involving stakeholders in prioritizing research areas that address societal needs. Impact involves applying scientific knowledge to promote positive change, enhance legitimacy, and reduce skepticism. Humility requires being modest about the contribution of science to society and acknowledging the values of the non-academic actors. These are important considerations while co-producing knowledge in TDR. The co-production of knowledge underscores the significance of non-academic stakeholders and acknowledges that the relationships among science, policy, and practice are multidirectional (Norström et al., 2020).

Four principles are central to the co-production of knowledge: context-based, pluralistic, interactive, and goal-oriented (Norström et al., 2020). Contextual factors include physical, environmental, technological, societal, political, interpersonal, intrapersonal, and organizational factors (Stokols et al., 2006) that influence research design and outcomes (Nagy et al., 2020) and are essential for improving stakeholder interaction quality (Brandt et al., 2013; Lang et al., 2012). In addition to this, contextual conditions in TDR include a) relevance of the research problem from the societal and environmental perspectives, b) conditions within research institutes, and c) competency of the researchers, i.e., experience, skills, values, and stakeholder engagement (Carew & Wickson, 2010; Woltersdorf et al., 2019). Understanding the research context is crucial for effectively involving stakeholders and managing activities. Additional factors, such as power asymmetry, incentives for participation, and history of conflict and cooperation affect the collaborative environment between researchers and stakeholders (Ansell & Gash, 2007). Factors such as needs, interests, and beliefs of social groups that may affect or be affected by the social process are essential for effective social interaction (Lang et al., 2012; Norström et al., 2020; Pohl et al., 2017). Moreover, the other principles such as pluralistic emphasizes on the multiple perspectives and goal orientation refer to specifying clear goals to

address the issues, whilst interaction is linked to learning among the actors involved throughout the research process (Norström et al., 2020).

Different researchers have discussed co-production of knowledge in various ways. For example, Pohl and Hirsch Hadorn (2007, pp. 20) stated four essential conditions for problem formulation: a) understanding the gravity of problems, b) considering both scientific perceptions and real-world challenges, c) connecting abstract and case-specific knowledge, and d) promoting knowledge and practices that are considered useful. Also, Lang et al. (2012) provided three stages of knowledge production in TDR: a) problem framing and team building, b) co-creation of solution-oriented, transferable knowledge, and c) (re-)integration and application of the created knowledge. Polk (2015) provided five principles of knowledge production: a) Inclusion – engaging stakeholders from research and non-research backgrounds, b) Collaboration – enhancing the quality of research through stakeholder involvement, c) Integration – combining diverse perspectives for the problem and solution identification, d) Usability – ensuring research is useful for both research and practice and e) Reflexivity - analyzing different perspective and expertise while framing problems and solutions. Pearsall et al. (2022) proposed four principles for equitable knowledge production at regional and global scales: a) focus on impacts, b) analyze pre-existing knowledge, c) sustain knowledge infrastructures over time, d) build 'spacecraft' of local communities. These principles outline the role of affected communities in decision-making, clarify stakeholder relationships, support knowledge infrastructures through funds, and recognize the knowledge, skills, experiences, and aptitudes that different stakeholders develop considering specific scales of influence. In a specific context of urban development, the knowledge production components entail a) understanding the goals and contexts, b) developing knowledge solutions, and c) outcomes for the research, policy, and practice (Web et al., 2018). These frameworks emphasize that co-production of knowledge is influenced by the role and importance

of contextual conditions, goals, integration of knowledge bases, urgency of issues, and scope of application of knowledge for science and practice.

Although stakeholder interaction is important to co-produce knowledge, it is equally important to understand the different outcome spaces in which TDR lands and what are their impacts on science and practice. Nutley et al. (2007) categorized research impact based on conceptual and instrumental uses. Conceptual use refers to changes in stakeholders' awareness, attitudes, and ideas, while instrumental research use refers to changes in policy frameworks. Broadly, the pertinent 'outcome spaces' outlined by Mitchell et al. (2015) are improvement in the situation, production, and dissemination of knowledge, as well as mutual transformational learning. These outcome spaces symbolize significant relationships among the situation, learning, and knowledge in relation to research and practice. The change in the situation change could be referred to as changes in socio-institutional change or policies. The knowledge generated from different disciplines proves that contextual conditions can be improved in a better way. Different uses of knowledge in various actions bring various impacts. The evaluation design that measures the societal impact would be useful in documenting the impact of transdisciplinary action.

In TDR, scientists and stakeholders share diverse backgrounds that benefit research in multiple ways. Nonetheless, there are also challenges to acknowledge. Co-producing socially relevant and scientifically accepted knowledge with different stakeholders is not as easy as it seems. Scientists working on generating knowledge face problems: the complex nature of sustainable research, the maintenance of impartiality, and the significance of scientific knowledge for decision-makers (Kueffer et al., 2012). Moreover, the challenges related to TDR included a) lack of awareness, dominance of the researchers, underrepresentation of the non-academic actors, and conflict in methodological standards (Lang et al., 2012). Other difficulties include gauging the interests of different stakeholders (Lemos et al., 2018) and developing the outreach plan (Zhuang et al., 2021) to achieve the societal impact of the research. The complexity of scientific

research involves addressing common interests rather than focusing solely on specific group interests. This challenge requires attention from diverse disciplines and stakeholders beyond academia (Miller et al., 2008). Likewise, the co-production of knowledge could be hindered by researchers' lack of experience, inadequate resources, and best practices for co-producing knowledge (Meadow et al., 2015). Additionally, the challenge of salience refers to presenting knowledge in an easily understandable and relevant way for decision-making is also important to acknowledge in TDR settings. Issues such as inaccessible information, irrelevance to decision-making, and lack of awareness contribute to this challenge (Cash et al., 2003). The impartiality challenge arises when research serves the common interest rather than the specific interest. To address these challenges, solutions include selecting problems that require stakeholder participation and framing questions to address society's specific problems through cultural and institutional change (Kueffer et al., 2012). Moreover, the researchers also need to strategize what conditions could be conducive to the transfer and use of findings in other cases (Adler et al., 2018). Some strategies that support co-production include being inclusive of participants' diversity and knowledge, reflexivity of credibility, legitimacy and accountability, and attention to the objectives of the co-production (Miller & Wyborn, 2020).

Prior research has discussed the significance of knowledge integration. Nevertheless, it has only been scantly reviewed (Zscheischler & Rogga, 2015). Existing studies often lack insights into the real-world impacts of research beyond the research process (Zscheischler & Rogga, 2015). Despite theoretical advancements in defining TDR, there is still a gap demonstrating a lack of clear understanding among researchers involved in such approaches (Zscheischler & Rogga, 2015). Despite this, co-production of knowledge distinguishes the TDR from the other approaches, as the focus is on designing the methods and practices for the future (Defila & Giulio, 2015). However, there is a lack of a common definition that amalgamates all the concepts related to transdisciplinary knowledge co-production. Literature also lacks a

universally agreed term to explicitly define a co-production of knowledge (Tembo et al., 2021). In a review, Bandola-Gill et al. (2023) summarized that co-production has been pervasively utilized across various fields and contexts. However, the co-production term is not well defined. The term knowledge co-production is scattered with a broader focus on generating new knowledge (Blackstock et al., 2007; Lang et al., 2012; Pohl, 2008;). Metz (2015) simplified how different terms are used across disciplines, yet no clear boundary exists. Not only consensus on the co-production of knowledge but there is also limited evidence on the impact of knowledge co-production on policy and practice (Khayatzadeh-Mahani, 2020). Not only the production of knowledge but also the need to know how co-produced knowledge is scientifically, socially, and policy-wise valid. Therefore, it is imperative to understand how researchers conceive and apply these concepts within the same case and encouraged us to design this current research study with the following research purpose and objectives. The research aims to study the understanding of stakeholder participation and co-production of knowledge. The objectives of this paper are as follows:

1. To examine researchers conceptual understanding of stakeholder participation and co-production of knowledge.
2. To explore how researchers incorporate stakeholder participation and co-production of knowledge into their research.

Methods

Project description

A project entitled, “Thriving Agricultural Systems in Urbanized Landscapes” (also called the Thriving Agriculture Project) was sanctioned by the United States Department of Agriculture's National Institute of Food and Agriculture (USDA NIFA) in 2019 ((*Thriving*

Agricultural Systems in Urbanized Landscapes, n.d.). This five-year project aimed to develop economically thriving and environmentally sustainable agricultural systems in the Urbanized Landscapes of the Chesapeake Bay Watershed over the next 25 years. Urbanizing landscapes refer to agricultural systems in metropolitan and non-metropolitan counties adjacent to metropolitan areas. The project entails 16 teams from Penn State, the University of Maryland, Virginia Tech, Ohio State, Utah State, George Washington University, the Stroud Water Research Center and a stakeholder advisory board. The stakeholder advisory board included key representatives from private and public sectors, and non-governmental organizations, spanning regional, state, and local levels within the Chesapeake Bay watershed. At the time of the data collection, there were 42 members representing faculty members, graduate research assistants, post-doctoral fellows, technicians, and the project manager. The 16 teams of researchers contributed expertise from various disciplines such as economic modeling, market analysis, watershed-scale nutrient management, and land use modeling. Disciplinary teams address project goals through regular interstate workshops by inviting various stakeholders to discuss the current issues and brainstorm solutions collectively. We intentionally used this TDR project for this research, as it allows the integration of various disciplinary teams by involving the concerned non-academic stakeholders to address the prevailing issues related to urbanizing landscapes in the Chesapeake Bay and envision a sustainable future.

Research design

A descriptive case research design was considered useful for this research study. A case study, as defined by Yin (2014) is, "*an empirical enquiry that investigates a contemporary phenomenon within real life context, especially when the boundaries between the phenomena and context are not clearly evident"* (p. 16). This design was particularly appropriate for the Thriving

Agriculture Project as it allows the study of a single case or investigation unit at a single point (Gerring, 2004) and advances knowledge of real-world complexity (Crowe et al., 2011, p.1). The Thriving Agriculture Project indicates the suitability of employing a descriptive case study to glean information about a multifaceted issue (Yin, 2014). This research aimed to collect participants' lived experiences and reflections regarding the TDR's various aspects within the Thriving Agriculture Project.

Participants in the research

The potential participants for this research were faculty members, graduate students, and post-doctoral fellows working on the Thriving Agriculture Project. A total of 21 researchers expressed their consent to participate in the research; the sample included 15 faculty members and six graduate students, with a gender composition of 13 males and eight females. The faculty members were at different stages of their career such as assistant professor to full professor, while graduate students were in master and doctoral degree program. However, both teams 14 and 15 were represented by the lead researcher and his faculty advisor and were excluded from the research to avoid any potential biases. Moreover, there was no post-doctoral fellow in the sample.

Data collection and analysis

Data were collected through semi-structured interviews conducted from March to June 2024. Of 21 interviews, 19 were conducted via Zoom, and two were in-person. The participants were interviewed using interview protocol which was developed based on research questions and literature. The interview protocol was divided into the following sections:

1) **Stakeholder participation:** This section examined the concept of stakeholder participation, its perceived benefits, the need assessment of stakeholders, and satisfaction with stakeholder participation. For example, *"What do you understand by 'stakeholder participation'?"*
2) **Co-production of knowledge:** This section focused on the concept of co-production of knowledge, approaches to using it with researchers and stakeholders, and the benefits it offers to researchers and stakeholders. For example, *"What is your understanding of the co-production of knowledge?"*

Participants were contacted via email, which provided an overview of the research and potential outcomes. Upon willingness to participate, the interviewees were sent the consent forms and interview protocol. The prior consent was obtained to record the interview and publish the findings in an aggregate (Kaisler & Grill, 2021). The study was conducted following the guidelines of the Institutional Review Board of the Pennsylvania State University.

To ensure the validity of the research, the interview protocol was sent to the dissertation committee and external reviewers (e.g., environmental sustainability, environmental sociology, transdisciplinary research, environmental governance systems, community development, stakeholder engagement, ecosystem science, and management) for their feedback. With the consent of the participants, the interviews were recorded and transcribed using Otter.ai software. The identifiers, such as names of researchers, stakeholders, and institutions, were removed from the transcripts to ensure anonymity and maintain the confidentiality of the data. For analysis, three transcripts were randomly selected and read well to gain an understanding of the data. The data were coded by lead researcher (first coder), and his faculty advisor (second coder). The data were coded to respond to research questions and identify the patterns and emerging ideas (Yin,

2014). The coding process involved both inductive and deductive processes. The initial process involved developing codes closer to the interviewee's responses. The codes were collected to understand the meanings, expressions, and intents of the participants, which were later emerged, segregated, or deleted in the direction of answering the research questions and developing a code book. The code book was continuously updated based on identifying newer codes and revising the initial codes. For instance, the second coder was not well-versed with the overall interviews and transcripts. Therefore, the understanding based on the transcripts was the only source. Both the first and second coders read the transcripts independently, discussed codes thoroughly including discrepancies in the codes, and developed a consensus. In this process, the meaning of the excerpts, definitions of the codes, and language of the codes were discussed precisely. Each transcript was coded following the code book, and new codes were generated wherever needed throughout the coding process.

We used descriptive coding, which means that transcripts were open coded in the first round of coding (Corbin & Strauss, 2007). In this process, codes were developed by reading the scripts, understanding the meaning, and reporting the codes as expressed in terms and expressions by participants. In the second cycle of the codes, axial coding was employed, where initial codes were reviewed, combined, and developed into bigger codes (Strauss & Corbin, 1998) to formulate the patterns and themes. In this coding cycle, axial codes were performed to merge codes into broader categories. This includes developing patterns from identical sets of codes and representing them in a story (Saldaňa, 2013). The information that may not contribute to answering the research questions was omitted. This is essential to identify emerging common patterns of the codes to synthesize in different themes (Creswell & Poth, 2018). Initially, the open coding was done throughout, which was later compared to identify similar codes and then merged into developing themes. In this process, themes were clubbed to form a category (Braun &

Clarke, 2006). The entire data was visited repeatedly to understand and confirm that coding is taking place as per the research goals. By visiting the data repeatedly, we immersed ourselves in it to identify its meaning and patterns and answer the research questions. Once all the transcripts were coded, the data was seen through a comprehensive lens to identify the long list of codes within the data set. This included combining various codes that convey the same meaning (Braun & Clarke, 2006).

Dependability and trustworthiness of research findings

From the qualitative aspects of the research, dependability and trustworthiness was established through four approaches: credibility (i.e., truthfulness), transferability (application to other research scenarios), dependability (i.e., replication of the research findings), and confirmability (i.e., confirming that research findings are free from any researchers' bias and prejudices, and emerged from the views of the participants) (Lincoln & Guba, 1985). As both the researcher and participants belong to the same project, it is possible to employ members to check whether the reporting of events, facts, data, and interpretation has been done correctly (Lincoln & Guba, 1985). In addition, transferability is related to a thick description of the findings, which means that research findings have the potential to be used and applied in other contexts. The confirmability denotes how the research has evolved over time and reported each stage critically. In this case, the confirmability of the research findings could be established by making field notes, writing memos, and personal reflections. Audit trailing was also done (Sandelowski, 1986) to ensure that future researchers can follow the decision-making process at the various stages of the research. For the credibility of the findings, panel testing of the interview protocol was conducted to ensure all the necessary questions were included sufficiently.

Results

This section presents findings related to stakeholder participation and co-production of knowledge. The findings address two major questions a) conceptual understanding and application of stakeholder participation and b) conceptual understanding and application of co-production of knowledge.

RQ1. Conceptual understanding and application of stakeholder participation

The conceptual understanding and application of stakeholder participation is presented in five sub-categories: conceptual understanding of stakeholder participation; application of stakeholder participation in the Thriving Agriculture Project; needs assessment of the stakeholders; perceived benefits of stakeholder participation; satisfaction and envisioning future relationships with stakeholders.

Conceptual understanding of stakeholder participation

The participants provided various responses when asked about their understanding of stakeholder participation. These responses are classified into two categories. Firstly, the findings contribute to our understanding of the conceptualization of stakeholder participation. Secondly, the findings reveal the ambiguity and uncertainty about stakeholder participation and its application. Hence, the major themes found were lack of clarity regarding stakeholder participation; collaborative research and stakeholder partnership; collaborative research design and implementation; stakeholder communication and information sharing; nature of stakeholder participation; stakeholder identification and involvement; and understanding practical situations and challenges.

Lack of clarity regarding term stakeholder participation

The participants conceived the term stakeholder participation in various ways. Some participants tried to collect their views on stakeholder participation from the term itself. There was confusion about whether stakeholder participation is a one-way or two-way communication process. It was also found that participants were trying to express the term based on how this term sounds. For example, one participant said, "*you could have a project where you have some presentations at the end of the project, you get some group of stakeholders together, you give some presentations on the results of the project, and technically, that would be participation, or is that really be engagement?"* [Participant 17].

One of the participants expressed that they were initially uncertain about what stakeholder participation includes in the research. It was perceived that only project sponsors were stakeholders in the research. It was also observed that the concept is understood as synonymous with the concept of stakeholder engagement. One participant stated, *"I think stakeholder participation to be personally kind of synonymous with stakeholder engagement."* [Participant 17].

Collaborative research and stakeholder partnership

Stakeholder participation was understood in a synergic view where researchers build collaborations with stakeholders. Participants perceived stakeholder participation as an opportunity to build collaborations with stakeholders to contribute to research proposals by thoroughly capturing their needs and benefits while valuing time. One participant mentioned, "*So developing a process for their participation that recognizes and brings returns to them is important, that means we are asking them for their expert advice, and they are feeling like they are contributing."* [Participant 14]. Such partnerships include their active, continuous, and iterative participation that keeps the researchers informed of their research process and ensures

the credibility of the findings. Another participant highlighted, *"Initially, the stakeholder participation also could be coming up with solutions with their practical knowledge and practical working in the field; farmers have more knowledge about their system than anyone else; they know their system better than us. It could be solutions and challenges which they face when we come up with solutions. So, also providing, they might have some solutions themselves, which they felt like, we may not always agree, but we could take that as feedback for things."* [Participant 07].

Collaborative research design and implementation

The role of stakeholders was critically emphasized in various aspects of the research process. Participants mentioned that stakeholder participation involves working collaboratively to explore and design research problems and questions that address common issues. They mentioned that stakeholder participation involves using information in practical applications through two-way interactions across different phases of the research process. One participant mentioned, "*stakeholder participation is really a two-way street; they are informing us that the things that are going on and us sharing our research."* [Participant 19]. The two-way interaction was emphasized to understand the needs and disseminate the research findings.

Stakeholder communication and information sharing

Participants viewed stakeholder participation from the communication and information sharing standpoint, where the role of the stakeholders is central to keep the researchers aware of ground realities. This way, the stakeholders make the researchers aware of recent trends (e.g., policy regulations) and provide input on current issues. As one of the participants mentioned, "*that helps us keep up with the trend, transformation of agriculture."* [Participant 09].

Nature of stakeholder participation

The participants also presented perspectives that included stakeholder participation in terms of the nature of the participation, which refers to how stakeholders participate in the research. This indicates the stakeholder participation in a formal role, e.g., stakeholder advisory board, throughout the research. Another school of thought related to their participation was related to their stake in the issue. As one participant mentioned, "*one is sort of the formal stakeholder participation, where we have the stakeholder advisory group, and we do very formalized activities with them."* [Participant 08].

Stakeholder identification and involvement

Another component of stakeholder participation was viewed as identifying and involving the stakeholders. In this situation, the participant mentioned that stakeholders are recipients of the information as well, where they receive the benefits of the research. Apart from this, the stakeholder identification entailed including those participants who are potential users of the information, and their role in '*causing and solving*' the problem. Additionally, it was also reported that the right stakeholders can help in informing the potential changes based on available data and addressing the problems. It was clear from one of the responses, *"Stakeholder participation, we think farmers getting farmers involved because their actions contribute to the problem, but they could also contribute to solving the problem. So that's one thing, In terms of stakeholder participation is participation by groups whose actions either contribute to the problem or could contribute to resolving the problem."* [Participant 03].

Understanding practical situations and challenges

The findings also uncovered the role of stakeholders in helping the researchers understand the ground realities of the situation. For example, it was imperative that stakeholder

participation informs the understanding of stakeholders' ground situation and policy implications. Such understanding helps the researchers to include these perspectives in the research and improve the research processes. One participant said, "s*takeholder engagement meetings which we have, those are few meetings where they've been contributing to the project from their perspectives about the challenges the issues."* [Participant 07].

The stakeholder questions and concerns capture the interest of researchers, inclining them to pay attention to specific issues that they had not previously considered or acknowledged.

The findings led us to conclude that participants conceived stakeholder participation as an active and iterative collaborative process aimed at supporting the researchers with current happenings outside the academic silos. The stakeholders play a significant role in identifying and revising research problems and designs and implementing the research in light of practical challenges and implications of the issues.

Application of stakeholder participation in the Thriving Agriculture Project

This section presents findings related to participants' perceptions about how stakeholder participation is integrated into the Thriving Agriculture Project. The findings have been classified into five major themes. These themes are labelled as awareness of the ground realities and tracking project progress, knowledge sharing, and refining the research process and outcomes. The two other themes included stakeholder needs and understanding, and strategic communication and transparency. The sub-sections cover detailed explanations of these themes.

Awareness of the ground realities and tracking project progress

When participants were asked to report instances of stakeholder participation in the Thriving Agriculture Project, they expressed that the stakeholders are helpful in making them aware of the ground realities of the Chesapeake Bay Watershed. Participants also expressed that stakeholder involvement helps them reflect on and assess their research ideas, which helps them be assured of the research progress. They mentioned that stakeholders keep them informed of ground realities, provide practical knowledge, and help them track the project progress, *"They really keep us grounded in reality. They keep us focused on the issues that are of importance. And they help us to guide and approve our research."* [Participant 17].

Knowledge sharing and updates

The participants also mentioned that through stakeholder participation they can share their current research and update what they are doing. In this way, they can support each other in a variety of ways, such as sharing the research findings, expertise, and outcomes. "*I think they're offering a lot. We are not familiar with day to day, or I am not familiar with the day-to-day challenges that farmers are facing. We learned a lot from; I remember learning a lot early on from the people doing kind of small operations that had animals and the challenges with slaughterhouses, not taking their animals or being far away or something like that*." [Participant 05].

Refining the research process and outcomes

The participants mentioned that stakeholders contribute to understanding the feasibility of implementation of the findings. This input helps to be realistic when planning the research

activities. Stakeholder participation plays an important role in improving research methods, models, tools and research designs. One of the participants mentioned, "*So the stakeholders helped to shape and define the scenarios, which is kind of the basis for exploring the research outcomes, ultimately*." [Participant 04].

Participants viewed in-depth discussions on farm profitability, zoning, land protection, and scenario development facilitate their consideration of the larger picture in the frame rather than focusing on their individual tasks. Participants perceived stakeholders contributing comprehensively at different stages of the Thriving Agriculture project.

Stakeholder needs and understanding

The participants perceived that involving stakeholders in research helps to understand what matters to stakeholders, especially their current or future needs. By including stakeholders in the research process, they acquaint themselves with stakeholder needs, which aids in considering the social aspect of the research. This also helps them keep the research aligned with the stakeholders' needs. As one participant mentioned, "*something to be implemented or something to be dissolved in society.*" [Participant 13].

Stakeholder participation in the research provided critical information: for example, the researchers could learn what stakeholders understood and did not understand from the findings. Researchers learned about the attitudes of folks invested in environmental improvements and production processes. Such information helps devise relevant and need-based information. Apart from this, there was an emphasis on the use of plain language in understanding. The participants opined that it is imperative to dialogue in a language and format that aligns with stakeholders' levels of comfort and communication style.

Strategic communication and transparency

Participants emphasized the need for two-way communication and transparency in interactions, where researchers and stakeholders are aware of the research process. As one participant mentioned, "*We sort of well first the research is shared with those that actually have an ability to make a change in the community, through policy or through practice. In a business from a government or a business entity or from a nonprofit. This is how we translate the science into action through stakeholder engagement and involvement.*" [Participant 12].

Needs assessment of the stakeholders

The participants were asked how they assessed the needs of their stakeholders in the Thriving Agriculture Project. The participants mentioned multiple methods that helped them understand what is important for their stakeholders and research, such as stakeholder engagement and learning, prior understanding and historically known issues, stakeholder identification from existing networks, and surveys and assessments.

Stakeholder engagement and learning

The participants expressed that the needs assessment of the stakeholders guides their research and improves decision-making. One of the approaches is learning with stakeholders. This approach included meetings, workshops, and on-farm research with stakeholders. For them, these are ideal avenues to jointly understand the data, stakeholders' practices, and willingness to adopt certain practices, e.g., nitrogen management. Some meetings are agenda-focused on "*What are your needs*?" [Participant 08]. Moreover, one of the participants specifically mentioned, "*ask*

them if it would change any of their practices or be helped by having any new tools for nitrogen management would be helpful to them." [Participant 01].

Prior understanding and historically known issues

When asked about ways of understanding the stakeholders' needs, the participants mentioned that many issues in the Chesapeake Bay Watershed are long-standing and need immediate attention. These issues are nationally discussed and prioritized. For example, nitrogen management improvement, a long-standing and historically known issue, needs immediate attention. One participant mentioned, "*Our research is sort of part of this long train of trying to improve nutrient management on farm there's a long history of in the research community of trying to improve nutrient management on farm, trying to reduce the excesses and the limitations from a nutrient management perspective. If we can increase the nutrient use efficiency of these ag. systems, we can help to make the farm we can help make crop production on farm more profitable. And that's the goal or desire of almost every or every producer."* [Participant 12].

Stakeholder identification from existing networks

One of the approaches used was identifying the stakeholders from the existing networks using different channels. This was based on their already known needs and shared understanding. It could be convenient to identify and work with already-known stakeholders rather than identifying new stakeholders. In this regard, one participant mentioned, *"We learn about them through different channels, they might have been involved with our extension educators before, maybe they have a certain crop consultant that has identified them as good candidates. They're farmers in our target area, i.e., [place] County, which is very urbanizing county, and has a lot of*

water quality issues. We sort of pull from that pool of farmers engaged in general with agronomic advisors and extension programs. Sometimes they're members of the [state], NO-TILL Alliance, and we get them through that. Sometimes, they are just their clients have a couple of different crop consultants that we work closely with, and the crop consultants kind of identify them as good collaborators." [Participant 01].

Surveys and assessments

One of the usual approaches used by the participants was surveys and assessments. The participants used surveys for the individual assessments of the stakeholders' needs, abilities, and comfort with the researchers. They also included surveys to collect feedback and multiple perspectives during meetings and workshops. As one participant mentioned, "*We're just going out to these grower groups and saying often we'll have them write on a piece of paper anonymously a question, because some of them are just to get a variety of voices, some of which might not be inclined to speak in front of the whole group."* [Participant 08].

Perceived benefits of stakeholder participation

In this sub-section, the participants were asked about aspects of stakeholder participation that improved or added new perspectives to their research. The participants received benefits in different ways, for example, a) need-based, relevant and practical research, b) access and documentation of data, c) real-world application, and d) fostering collaboration

Need-based, relevant, practical research

We found that stakeholders' input helped researchers conduct need-based research; for example, the stakeholders guided the researchers to work on the cover crops. The researchers acknowledged and worked in the direction of the stakeholders' input, which resulted in setting up experiments that cater to the present and futuristic needs of stakeholders. As one participant mentioned, *"I think it should be focused on things that our stakeholders will need tomorrow, not just today, and that's a critical part of the overall process. So that's, what stakeholders the advantages, I think, of bringing stakeholders into that conversation is that contextual piece and relevancy."* [Participant 10].

Access and documentation of data

This theme explores the benefits of collecting primary information and documenting the success stories of the project. With the help of stakeholder contribution, the researchers could access field level data. As one participant mentioned, "*I think having these on-farm collaborators that we set up experiments on their farms. We get access to all of these different soil types and management systems and levels of manure usage*." [Participant 01].

Real-world application and learning

This theme provides details of benefits, especially in learning about new research opportunities, such as introducing agricultural products to markets and adding food delivery components. The researcher was able to learn about real-world challenges; for example, one of the stakeholders helped to broaden their understanding of the lack of processing plants in his area and the challenges in the direct marketing of beef. Additionally, understanding specific

instances and the interchange of information where research is needed was significantly beneficial. As one participant mentioned, "*Some of the kinds of insights that stakeholders have been able to provide, they are very practical issues. They're not high-level theory. They're very practical issues and concerns.*" [Participant 17]

Building partnerships and fostering collaboration

The theme explores the benefits of stakeholder participation, particularly in building new collaborations and fostering existing ones. It was found that stakeholder participation contributed to stakeholders in developing stakeholder networks, inclusion of integrating local government expertise, building trust within communities and expansion of current partnerships. As one participant mentioned, *'We've relied very heavily on kind of building out our list of participants in the workshops and on the stakeholder advisory board through our knowledge of people from previous projects."* [Participant 17].

Satisfaction and envision of future relationships with stakeholders

Stakeholder participation plays an important role in improving and adding new perspectives or directions to the research in the Thriving Agriculture project. Therefore, there is ongoing participation of stakeholders in the research in various capacities contributing at various levels. It was imperative to understand the satisfaction of researchers from the stakeholders' participation. From the findings, it was found that most of the participants were satisfied with stakeholder participation and their contribution being received to individual tasks or the overall projects. One of the participants mentioned, "*I'm very satisfied with their participation."* [Participant 14]. The participants were satisfied with their contribution to research, e.g.,

developing scenarios, field operations, and insights on the outcomes of experiments. The participants revealed that they were satisfied with the way the stakeholders addressed their questions. However, there were some instances where dissatisfaction was expressed. To exemplify, "*I didn't feel that the breakout discussions were always getting to us to the places where we would like to get to with stakeholders."* [Participant 20].

Following up with the satisfaction, it also explored how participants envision their existing relationships with the stakeholders in the future. It was investigated to see if they would like to continue working with a stakeholder advisory board or their individual stakeholders (e.g., farmers) beyond the project cycle. The findings are broadly classified into three categories: a) continue to engage, b) difficult to engage, and c) conditional engagement. Firstly, the participants were satisfied and willing to continue engaging in future projects. Considering shared understanding and working relationships with their stakeholders, it is easier for them to continue working with them. They anticipated the opportunities of working together in refining models, sharing results, and seeking feedback. One participant mentioned, "*the thriving agriculture has built the relationships we established with stakeholders in previous projects that will carry forward.*" [Participant 17]. On the other hand, the participants mentioned that engaging beyond the project life might be difficult due to long-term commitments and funding constraints. One participant said, "*But without further funding, I don't see a lot of engagement moving forward, just because I wouldn't have funding from other projects to do that.*" [Participant 20]. Lastly, the participants expressed that it is possible to engage with current stakeholders. Then again, it is subject to factors such as whether future projects would align with stakeholders' interests and the location and scope of the project. One participant said, "*I would want to work them, but it's just kind of maybe they're in a different geography. They're focused on different aspects of the food system than what we focus on in the work of our senator in my work*." [Participant 04]. Therefore, several factors affect stakeholder participation in future collaborations.

RQ2: Conceptual clarity of co-production of knowledge and perceived benefits of co-production for research and stakeholders

This section addresses the question related to conceptualization of the co-production of knowledge. It contains findings on conceptual understanding of the co-production of knowledge, the contribution of the co-production of knowledge to research, and researchers' perception of the benefits of co-production for stakeholders. In the case of the benefits of co-production of knowledge, the benefits of co-production for the stakeholders were learned through the perception of researchers.

Conceptual understanding of co-production

The main themes in this subsection were collaboration for knowledge production, the application of scientific knowledge, stakeholder feedback and engagement, collaborative research and problem-solving, two-way communication, and confusion and uncertainty.

Collaboration for knowledge production

Participants deliberated the co-production of knowledge is a collaborative process that generates new ideas and research products while aligning with the project's goals. This process fosters co-learning where researchers and stakeholders jointly analyze the common issues, refine, and continuously update the research process. Moreover, the stakeholders contribute to data collection and further validate the information, and above all, they benefit each other. As one participant said, "W*e are producing a product that we are producing knowledge that maybe does not generate does stem solely from my own research, my own the models that have developed, but it stems also from perspectives, perhaps models that others that I'm working with have developed*." [Participant 03]

Application of scientific knowledge

The participant mentioned that the co-production of knowledge involves the application of scientific knowledge into theory and practice (e.g., policy implementation). One participant explained, "*they would take outputs from your models and try to use that as inputs into the best way to implement policies in their particular location*." [Participant 19].

Stakeholder feedback and engagement

The participants mentioned that utilizing stakeholder feedback supports the research development, design, and delivery. The stakeholders exchange information on various issues and in various contexts. One participant, "*They can provide feedback and say, this was useful to me, or this is not useful at all. And here's why, and then you should kind of learn understand why it wasn't useful."* [Participant 01].

Collaborative research and problem-solving

This theme presents information related to the role of the researchers and stakeholders, where both parties integrate their perspectives to better define research goals, process, and outcomes. One of the participants mentioned, "*from the very beginning of that project, you are working with the stakeholders to define research goals, to develop methods of design, and creating this feedback loop*." [Participant 04].

Two-way communication

Participants provided a very generic view of co-production of knowledge: it is a two-way interaction between researchers and stakeholders. It is not a detailed expression of clarity on how it is a co-production of knowledge. One of the participants mentioned, "*I would define it as sort of a two-way interaction between academics and non-academics.*" [Participant 19].

Confusion and uncertainty

We also learned that participants expressed confusion and lack of certainty about the co-production of knowledge. The participants clearly mentioned that they had no idea about this term, and also some participants provided a very generic overview of the term, which was not beneficial to build an understanding of the co-production of knowledge. One participant mentioned, *"This term is actually new to me, I have never heard the word is."* [Participant 16].

Contribution of co-production to the research process

This section gains insight into the contribution of the co-production of the knowledge process to the research process. The key contributions entail accountability towards stakeholders, awareness of new research priorities, dissemination of knowledge for broader stakeholders, and improvement in the research methods and application.

Accountability towards stakeholders

In the Thriving Agriculture project, there were certainly opportunities that participants believed that it enhanced their accountability to serve the stakeholders through direct engagement and self-motivation to address the challenges. Moreover, the co-production of knowledge helped them to readjust their research priorities to meet the expectations of the stakeholders based on

their feedback. One participant said, "*Starting in about 2010-12, I started engaging more with farmers and doing work that was motivated by more immediate needs of those farms, but also the watershed to Chesapeake Bay watershed issues*." [Participant 08].

Expanding research horizons and stakeholder engagement

This theme highlighted stakeholders' awareness, collaboration, and practical knowledge in the research process. More specifically, participants opined that working with stakeholders enhanced their awareness of the new research areas and questions, such as understanding the challenges in food processing and marketing. The co-learning spaces enhanced practical knowledge (e.g., learning about the consumers' willingness to pay for local products) and problem-solving ability. One participant mentioned, *"For me, one of the works up and meeting with the stakeholder. They are always in every workshop, or in every meeting, somebody will arise a question saying that? How do we know how sustainable we are? How do we know how sustainable we are? How do we know? What is the impact of my tasks that I have been doing for one year, two-year 10-year, people asked that question?"* [Participant 13].

Dissemination of knowledge for broader stakeholders

The other area of the benefits mentioned by the researchers is the dissemination of information for broader communication. More specifically, participants mentioned engagement with stakeholders to help them improve translating the research findings for broader audiences and ultimately enhancing the use of findings (e.g., writing papers). As one participant said, *"It is important to know how to give information to other people so that they can actually use it."* [Participant 05].

Improvement in research methods and application

Participants feel that by stakeholder engagement in the Thriving Agriculture project, they have reported considerable improvement in the research. They mentioned that co-production aided in improving research components and shifting to newer research areas. In addition to this, they have also reported a remarkable change in the research quality and anticipation of future research benefits. One participant mentioned, *"It helps to make the research more relatable, more applicable to real-world scenarios. it strengthens the research basically."* [Participant 12].

Researchers' perception of benefits of the co-production for stakeholders

This section presents the view of the researchers regarding the potential benefits of co-production for the stakeholders. The stakeholder's participation in Thriving Agriculture is not incentivized, but they extensively contribute their time, expertise, and efforts. It is essential to determine what is for them in return for their contributions and efforts. Therefore, we asked participants to report the potential benefits of co-production of knowledge for the stakeholders. It was found that they perceived that it potentially benefits the stakeholders in many ways, including, a) increased access to information and resources, b) improved awareness and learning about the research issues, areas, and opportunities, c) broadened networking opportunities, and d) improved scope of action and application of research.

Increased access to information and resources

When asked about how researchers perceive the knowledge that is co-produced is helpful to stakeholders and justifies their time, efforts, and expertise in the project. Participants mentioned that the co-production of knowledge facilitated the stakeholders in accessing the

information in plain language and site-specific information (e.g., different soil properties in their farms). Moreover, the free information offered to stakeholders (e.g., farmers) also aids in cutting down operational farm costs. One participant said, "*that suggests that there is a lot of interest in getting the answers to specific questions, getting better data on these things*." [Participant 19].

Improved awareness and learning about research issues, areas, and opportunities

The participants also perceived that the co-production of knowledge activities in the Thriving Agriculture project aided in understanding the current state of the research. The farm tours and interactions at various meetings and workshops provided valuable perspectives on the challenges of different regions. Stakeholders availed themselves of the opportunity to attend various events that helped them become aware of current affairs. One participant mentioned, *"They probably are also interested in learning what researchers, these people in the universities are doing, trying to do to address important social issues."* [Participant 16].

Broadened networking opportunities

Many workshops were organized in different states over the years, and members of the stakeholder advisory board and general stakeholders were invited. The participants perceived that attending these workshops introduced stakeholders to other stakeholders based in different states, which helped broaden their networking. One participant mentioned that it is "*because they get to know the stakeholders in all three states, and also how their program applies or doesn't apply and the stakeholders' issues in all three states.*" [Participant 02]. Eventually, this helps to know the essential aspects of issues in detail.

Improved scope of action and application of research

The participants mentioned that engaging with researchers in the Thriving Agriculture Project helps to inform policy decisions, get directions for resource allocations (e.g., local food), and strengthen the decision-making for resource allocations. The outcomes of such interactions facilitate applying knowledge into adjusting dates of cover crops or improving the water quality in general or Chesapeake Bay Watershed particularly. One participant said, *"You probably also want to expand that as much as hopefully you are pushing that penetration as far as you can then, then that area where we are relatively low evaluations of these kind of products, then that's probably area you should focus on. These kinds of detailed information develop. The knowledge is what we expect to give them to help you, to guide their decisions."* [Participant 21].

In summary, it could be concluded that both stakeholders and researchers benefit from participating in the TDR. These benefits could collectively be seen through the lens of relevancy, needs-based, and practical knowledge situated in a clear understanding of the ground realities of complex issues and the need interface between science and society.

Discussion

The study aimed to understand and determine the linkage between conceptual understanding and empirical use of stakeholder participation and co-production of knowledge using the Thriving Agriculture project as a case study. The key findings revealed significant variability in the understanding of stakeholder participation and co-production and their application in the Thriving Agriculture project. Some researchers broadly view it as one-way communication versus two-way communication. Van Buuren et al. (2019) emphasized that stakeholder engagement is related to multiple stakeholders working on policy and decision-

making. In contrast, the co-production of knowledge is linked with co-developing scientific knowledge between stakeholders from academic and non-academic backgrounds.

Stakeholder collaboration is recognized for developing sustainable solutions for complex challenges. However, such interactions depend on the project's potential contribution, the form of knowledge desired, the complexity of the issues, and how the interactions between the researchers and stakeholders exist (Schneider & Buser, 2018). The findings related to understanding of stakeholder participation are two-fold. Firstly, we found a lack of clear understanding and confusion with other approaches. There was a struggle to define what stakeholder participation entails. Secondly, we found that stakeholder participation is perceived in terms of the nature, role, and contribution of the stakeholders. The participants reflected on confusion related to how stakeholder participation differs from stakeholder engagement. There were ideas about whether participation refers to delivering the presentations or research results or if participation goes beyond merely sharing the results. Wyborn et al. (2019) assert that co-production needs to go beyond stakeholder engagement. Overall, the confusion rested on the extent of how the stakeholders are positioned in the research process in terms of what they should be offering and receiving in two-way interaction. It could be inferred that lack of certainty could stem from the nature of research, and deliverables associated with each participant. Working with stakeholders is linked with the social aspect of the research. Admittedly, all researchers are not professionally trained and feel the need to engage with stakeholders outside the academic boundaries. For example, the sample comprised a diversity of researchers from multiple backgrounds, i.e., natural sciences to social sciences. Usually, they work with stakeholders at scales aligning with the demands of their research or as required by the funding agency. This could be one of the reasons for the uncertainty and variability in the responses. This ambiguity can be preventive in realizing potential benefits of stakeholders' participation.

Nonetheless, the research showed that stakeholder participation includes partnerships, research designing, communication, two-way engagement, and understanding practical challenges. These findings broaden our understanding of various dimensions of stakeholder participation. More specifically, the findings on how stakeholder participation is utilized in the Thriving Agriculture Project are useful to report the actual application of stakeholder participation. For example, the Thriving Agriculture Project benefits from stakeholder participation. Because of that, the researchers can refine their research questions, models, and designs based on the input of ground realities added by the stakeholders. Researchers benefit from the contribution of the stakeholders as they play an instrumental role by continuously letting the researchers know what is happening to information delivered to stakeholders. Moreover, stakeholder participation adds social value to the research conducted in the Thriving Agriculture Project. Social value refers to learning about the stakeholders' attitudes, willingness, and challenges. Despite the researchers mentioning certain instances of stakeholder participation in the Thriving Agriculture Project, there was a lack of contextual clarity in terms of precisely expressing the specific examples, which could help understand the specific contributions of the stakeholders.

To benefit and improve the research process, the researchers were found to be using several methods to develop need-based and relevant research. Apart from the traditional methods of need assessment, i.e., surveys, workshops, and meetings, we also found that researchers focused on long-standing issues and historical known problems and relied on existing stakeholder groups to identify research needs. These methods aid researchers in working on the problems that need immediate attention, priorities regional or national levels, and ensuring that outcomes are applicable and relevant. However, the Thriving Agriculture Project has undertaken no formalized need assessment. The reported need assessments are conducted in discussion style during the workshops and meetings, but not through research conducted before commencing the research. It

is not only limited to stakeholders' needs but also need to conduct research on stakeholders' preferences for the research engagement (Bieluch et al., 2017). The knowledge of what TDR aims to achieve helps to make informed decisions, envision goals and practice with assurance (Mitchell et al. (2015).

It was also interesting to examine the perceptions of satisfaction with stakeholder participation. The findings revealed that the researchers are satisfied with the extent of the stakeholders' contribution. They acknowledge the limitations of the stakeholders in terms of time, effort, and expertise. Moreover, they are not incentivized for their services to the project. However, incentivizing the stakeholders could be a way forward to seek their enhanced contribution (Arnott et al., 2020; Satterthwaite et al., 2024). To ensure that stakeholders are satisfied, there needs flexibility, negotiation and regular assessments of the stakeholders' needs and preferences (Bieluch et al., 2017). We acknowledge this research has drawbacks for not capturing stakeholders' perspectives on this. In addition, we explored how different researchers envision their future collaboration with the stakeholders. The findings are broadly categorized into three categories: a) continue to engage, b) difficult to engage, and c) conditional to engagement. The stakeholders anticipate collaborating with the current network of stakeholders in the future. These stakeholders are a part of their network, which they have been working on for a long time (Lang et al., 2012) or have nurtured working in the Thriving Agriculture Project. They perceive synergy in collaborations. The perception of difficulty in continuing is based on the project needs, research priorities, and availability of resources and stakeholders.

Co-production is applied across various disciplines and contexts (Miller & Wyborn, 2020; Wyborn et al., 2019), yet the meaning of co-production is not well defined (Bandola-Gill et al., 2023). In the case of exploring the conceptual understanding of the co-production, two strands of findings were found. Firstly, it was found that there persists a lack of surety among the researchers about aspects of co-production. The need for a conceptual understanding of co-

production and its application was realized (Voorberg et al., 2015). The co-production is intensive and committed effort, that requires understanding of different modes, and their application and challenges to achieve specific outcomes (Chambers et al., 2021). There is also no practical guidance on how and when the co-production of knowledge is to be employed (Satterthwaite et al., 2024). Secondly, the findings helped to determine the understanding of co-production of knowledge. Findings showed that researchers think the co-production of knowledge is a two-way process that allows the production and application of knowledge to address complex problems with input from researchers and stakeholders. The findings are supported by Satterthwaite et al. (2024), who conceptualized the co-production of knowledge in terms of co-designing the knowledge to address complex sustainability issues. Moreover, the emphasis on jointly producing knowledge with multiple partners and ensuring the knowledge is useable are the important components of the co-production process (Dilling & Lemos, 2011; Lemos & Morehouse, 2005). The knowledge for addressing intricate problems needs to be produced across multiple knowledge systems (Bandola-Gill et al., 2023). The findings are aligned with Norström et al. (2020) view of co-production, where stress upon the co-production of knowledge surpasses the knowledge aspects and aims to build trust, foster collaborations, and understand the practical impacts of the research. Chambers et al (2021) provided rich understanding of the approaches those varied according to need for co-production, influence of power and politics, and impact pathways from the in-depth analysis of 32 cases of co-production.

The research also explored the benefits of the co-production of knowledge for the researchers and stakeholders in Thriving Agriculture Project. The two-way understanding was important to determine researchers' vision of how collaborative efforts are benefitting both participating parties. The findings demonstrated that the researchers benefitted from ways such as enhancing their accountability of research for stakeholders, expanding horizons and stakeholder engagement, and improving the research findings for wider audiences. The success of co-

production lies in integrating stakeholders in defining the research problem, formulating questions, and role in data collection, analysis, and dissemination of knowledge (Lemos & Morehouse, 2005). Moreover, one of the driving factors for co-producing was to address the longstanding issues (Chambers et al., 2021).

Nonetheless, the researchers perceived that stakeholders also benefitted from advancing their networks with other stakeholders in other states, accessing scientific information readily, freely, and in a version that suits their ability to understand. Moreover, stakeholders benefitted from being aware of the latest research issues and opportunities. Ultimately, the credibility of information helped them enhance the adoption of information and, consequently, increased the impact of the research. Weighing the benefits for both parties, co-production has successfully fostered collaborations and access to resources and information (Satterthwaite et al., 2024). In the co-production of knowledge, the contribution is considered to tackle societal problems (Wyborn et al., 2019).

Implications of the research

The findings have implications for both researchers and stakeholders. For researchers, the study identified a considerable gap in the conceptual understanding of stakeholder participation and co-production of knowledge. TDR brings together diverse stakeholders who have diverse backgrounds, knowledge and view of the problems, and approach to address them (Mitchell et al., 2015). These factors might have contributed to differentiated understanding of the stakeholder participation and co-production of knowledge. These knowledge gaps could potentially impact applying these concepts in TDR, which could considerably limit the scope of research in terms of co-designing the research process, disseminating information, and engaging stakeholders. It is recommended that researchers discuss their beliefs and motivations openly and, of course, with funding agencies and folks in the decision-making power (Mitchell et al., 2015). The diversity is

reflected in the characteristics and history of the researchers and their perceptions of the TDR process and practice (Mitchell et al., 2015).

Despite the knowledge gaps, the findings draw the attention of the researchers for institutional support and capacity building through TDR-focused programs. The TDR requires preparation to understand and adapt owing to inherent differences in the cultural and linguistic of the participants (Jakobsen et al., 2004; Mattor et al., 2019). Such programs can potentially orient researchers to understand their positionality and analysis of scientific and social skills toward developing sustainable solutions to contested problems. To develop salient, credible, and legitimate research (Cash et al., 2003), a formal need assessment is needed to produce need-based, relevant, and applied findings.

The current study has provided findings from the data collated at one point only; however, TDR inherently requires time to come to fruition. Therefore, a longitudinal evaluative approach would be justifiable in reporting the patterns of changes in the research. Such studies would be helpful to study how the roles of the researchers and scientists, as well as their relationships, priorities, and interests, have changed over time and with effects on the outputs, outcomes, and impacts. Future studies should include a larger sample to deepen understanding of stakeholder participation and co-production concepts and assess their practical applications in the projects. Moreover, these studies could also consider cross-comparisons across different projects to explore how stakeholder participation and co-production are perceived and practiced in different contexts. Identifying similar and dissimilar patterns would help to refine and critique the definition and contribute to theoretical frameworks of the co-production and guide practical guidance. This study relied on the researchers' perspectives of the co-production of knowledge benefits for them and their perception of the stakeholders' benefits. Future studies could include stakeholders' perspectives to gauge their satisfaction, perceived benefits, and future orientation to engage in projects addressing complex problems. Finally, the study emphasizes the need for

capacity building through training, workshops, and practical experiences to enhance research capability to meet the desired and emerging needs of sustainability challenges, funding agencies, and society at large.

Limitations of the research

The study has certain limitations that need to be acknowledged. First, the study is based on qualitative research design; there are no inferential statistics, which restricts understanding of the findings in quantitative terms (Tobias et al., 2019). Second, the research doesn't collect the demographic profile of the researchers, e.g., research experience in TDR, stage of career, etc. The data on these variables could be instrumental in concluding more confidently. Third, it is admitted that the generalizability of the TDR findings is a limiting factor (Adler et al., 2018). The small sample size of the research study limits its generalizability, and findings have emerged from a single case study. To overcome the issues of generalizability, the study needed to be expanded to broader stakeholders and scientists (Thompson et al., 2017). Fourth, despite promising findings, the findings are limited to the perspectives of the researchers only. A deeper understanding of TDR by involving stakeholders' perspectives is needed (Chammas et al., 2020). This could present a two-way understanding and verify some of the claims made by either party. Fifth, the findings are limited to a single case study only. Therefore, comparative research on various SAS-funded projects is needed to report trends in the conceptual understanding of stakeholder participation and co-production and their application in the respective projects. This could serve richer data to identify various variables and potentially refine or critique existing or develop newer theories of TDR.

Conclusion

The study aimed to assess the conceptual understanding and practical application of stakeholder participation and co-production of knowledge in the Thriving Agriculture project. The research revealed a knowledge gap in conceptual clarity in these processes. More specifically, stakeholder participation is an active and reciprocal relationship between the researchers and stakeholders to discover the solutions to problems that need immediate attention. The research showed substantial satisfaction from the stakeholders' involvement in the research process that researchers desire to continue and nurture their existing stakeholders' relationships in future research projects. However, the consideration of resources, the nature of research, and the alignment of the research areas with the priorities of stakeholders were identified as factors influencing the sustainability of these collaborations. However, the use of a single case study limits generalizability. Future research could use a larger sample size, cross-comparisons, and longitudinal research design for deeper exploration of knowledge and application of concepts of TDR, i.e., stakeholder participation and co-production of knowledge. Future research could employ mixed-method research to understand TDR through the lens of qualitative and quantitative research.

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Appendix B: Interview Protocol

We appreciate your willingness to support our research, which aims to understand the perception of researchers about the stakeholder participation and co- production of knowledge, outcomes, and the impact of Transdisciplinary Research in the Thriving Agriculture project. Your participation is fully voluntary. Kindly feel free to stop me if you have any questions/concerns or do not want to answer any of the questions. I will read the informed consent form and appreciate your verbal consent before I start this interview. Upon agreement to informed verbal consent, I would like to record the interview if that is okay with you.

Stakeholder Engagement

1. What do you understand by 'stakeholder participation'?
2. To what extent 'Stakeholder Participation' offers any contribution to the research in the Thriving Agriculture Project? Kindly elaborate your answer.

3. Are you currently collaborating with stakeholder groups in Thriving Agriculture Project?
    a. *If yes, (Move to questions 04)*
    b. *If No, Move to questions, 08)*

4. Who are those stakeholders?

5. How are you assessing the needs of your stakeholders to guide your research processes in Thriving Agriculture Project? Kindly provide some examples.

6. Could you elaborate which aspects of stakeholder participation improved or added new perspectives to your research?

7. How satisfied are you with the stakeholders' participation in the project?
    a. What do you expect in terms of future relationships with current stakeholders?

8. Why are you not currently working with any stakeholders?
    a. Do you intend to include stakeholders in your research? If yes, what group of stakeholders do you intend to include?

        a. How will these stakeholders can contribute to your research?

Co-production of knowledge

The term co-production of knowledge is increasingly used in conferences, workshops or by funding agencies.

9. What is your understanding of the co-production of knowledge?

Co-production of knowledge refers to a collaborative process that involves mutual learning among academic and non-academic stakeholders to improve and create new knowledge to envision a sustainable solution to a complex problem.

10. Would you mention any example of how co-production of knowledge is taking place within the Thriving Agriculture Project?

10a. How are you engaging (both formally and/or informally) with the stakeholders for your research within the Thriving Agriculture Project?

11. What has been the co-production of knowledge in the Thriving Agriculture Project influenced your research? Kindly share some examples, (e.g., changing your perception, getting new directions for research).

12. How have the different project activities (e.g., workshops, meetings, farm tours) benefited the non-academic stakeholders in the project?

Output-outcome-impact

In this section, we aim to understand the potential outcomes, dissemination of findings and impact of the research at different levels (e.g., social, environmental etc.).

a. How has your current research influenced the stakeholders? What are the social impacts of your research on CBW residents and beyond (e.g., changes in networking, individual and organizational practices, change in knowledge)?
b. What is the scientific impact of your research in your field and beyond (e.g., changes in the research problems, research practices, number of papers/citations)?

13. What are the potential long-term implications of your research in the Thriving Agriculture Project?
    c. Could you describe how your research aims to bring about economic or environmental-based policy changes?
    d. How do you think that your research is being shared effectively across the research and stakeholder groups? Kindly provide some examples.

Chapter 4

Identifying Core Competencies Required for Evaluators to Evaluate the Transdisciplinary Research Projects

Abstract

Wicked problems, characterized by their complex nature and interconnectedness, necessitate transdisciplinary research (TDR) approaches that integrate diverse disciplines and stakeholders to address their multifaceted challenges effectively. Several frameworks, principles, methods, and guides have been suggested for evaluating TDR. However, a community of peers who could evaluate the quality of TDR is lacking. The scientific literature shows a considerable gap in core competencies needed for TDR evaluators, yet only practical guidance is for regular program evaluators. Still, those skills are not sufficient, considering the breadth of the TDR process.

To narrow these research gaps, a three-round modified Delphi study was conducted from April to August 2024 by selecting a diverse expert panel of 26 panelists (e.g., educational qualification, years of experience, and area of expertise) from 41 projects that were funded under the Agriculture and Food Research Initiative's Sustainable Agricultural Systems (SAS) program area of United States Department of Agriculture's National Institute of Food and Agriculture. Three rounds of data collection were conducted through an online survey by Qualtrics. Our analysis revealed a set of 60 competencies reflecting critical areas of TDR, data collection methods, ethical considerations, interpersonal skills, program planning, and management. There was a hundred percent agreement for nine competencies, for example, conducting responsible evaluations (i.e., ethical conduct, fairness, stakeholder engagement, and accountability). Further analysis of the competencies in light of the American Evaluation Association framework (2018) revealed that the majority of competencies fell into the methodology (31.7%, n=19) domain followed professional practice (15%, n=9), context (13.3%, n=8), planning & management (10%,

n=6) and interpersonal (10%, n=6), the rest of competencies that were explicitly related to TDR were classified into a new category, 'Unique to 'TDR'. This category captured 12 competencies, for example, understands theory and practice of TDR. Our findings guide TDR evaluators to consider these competencies while engaging in the evaluation pursuit. Moreover, the funding agency and evaluation capacity development initiatives supporting transdisciplinary projects should include and support these competencies in the skill development training programs.

Keywords: Wicked problems, Transdisciplinary research, Delphi study, consensus, program evaluation

Introduction

Complex problems (e.g., climate change, water quality and quantity), also called wicked problems, are characterized by a lack of clear definitions, and solutions, are inherently unique (Rittel & Weber, 1973). Addressing such problems requires a collaborative approach to develop innovative methods that can respond to challenges related to such complex issues (Palmer-Abbs et al., 2024). Therefore, TDR demonstrates immense potential and approach and involves the integration of diverse academic and non-academic stakeholders (Jahn et al., 2012; Lang et al., 2012; Lawrence & Després, 2004; Pohl, 2011; Hoffman et al., 2017; Mauser et al., 2013). By fostering collaborative actions and a unified vision for addressing these complex issues, TDR fosters shared learning (Stokols et al., 2003). Prior research suggested that the greater the application of TDR principles in the research, the greater contributions and influence it is expected to achieve (Belcher et al., 2019).

Concept and application of TDR

TDR is defined as "*a reflexive, collaborative approach to knowledge co-production, inclusive of academic and non-academic actors and stakeholders, to integrate diverse types of knowledge, consider risks and consequences, and generate practical solutions to societal problems*" (Holzer et al., 2018, p. 809). The three-phase ideal-typical framework of TDR is well-recognized to define the TDR process (Lang et al., 2012). The first phase entails building research teams, understanding goals, designing research objectives and questions, and collaborative knowledge production. The second phase includes defining the roles of the practitioners and researchers, and methods for knowledge generation and integration. In contrast, the third phase

emphasizes the two-way integration of scientific and local knowledge and informs theory and practice (Lang et al., 2012). To understand the impacts of TDR, Schäfer et al. (2021) classified the impacts of the TDR into three orders based on the degree of effects, i.e., the ability of newly produced knowledge to tackle the complexity of problems. First-order effects are a project's direct, immediate, and observable consequences. These effects can be seen locally and nationally through research publications and presentations. The second-order effects, also called intermediary effects, are outside the scope of the project but are in proximity of space and time of the project. These effects include outcomes that can be planned during a project and depend on external resources, e.g., developing proposals for next-stage grants. However, the changes beyond the project's spatial and temporal context describe the third-order effects. These are long-term changes beyond the project's duration and are hard to capture systematically after a certain period, such as changes in laws and regulations. Therefore, evaluation of research process, outcomes, and impacts of TDR is important, requires significant planning and execution.

Significance of evaluating the TDR

As a discipline, evaluation serves multiple purposes, including but limited to enhancing the effectiveness of projects, ensuring accountability to funders and research participants, assessing impact, and understanding resource allocation. The two main forms of evaluation are formative and summative. Formative evaluation focuses on improving the effectiveness of project activities and interventions while projects are ongoing, while the summative evaluation assesses the overall worth of project in totality at the end (Yarbrough et al., 2010). Formative evaluation allows feedback integration to enhance research quality (Verwoerd et al., 2020). However, measuring social impacts requires a long-term approach where only summative evaluation would

not be adequate (Blackstock et al., 2007; Walter et al., 2007). Monitoring and evaluation assessments are hindered by the absence of institutional support in terms of incentives, procedures, and evaluator skills (Kny et al., 2023). In the specific context of TDR, evaluators are expected to consider how the research engages with context, how the process is evolving, and what products are being developed (Carew & Wickson, 2010). TDR provides new conceptual frameworks for problem analysis and developing evidence-based policy recommendations (Stokols et al., 2003). Evaluating TDR includes determining whether predefined expectations of academic and social actors, such as planners and policymakers, have been met. Moreover, the inclusion of social researchers with expertise in the evaluation process has also been emphasized (Kny et al., 2023; van Drooge & Spaapen, 2022). However, including stakeholders outside the academic setting and understanding the benefits is challenging (Belcher et al., 2016). Funders' requirements and interests continuously increase to include social aspects, e.g., stakeholder-focused research (van Drooge & Spaapen, 2022). To meet funding agency and stakeholder expectations and maximize societal impact, evaluation measures must effectively capture TDR's full range of contributions. Therefore, the evaluation process must begin early and remain flexible to accommodate emerging changes over time and understand information use (Kny et al., 2023; Walter et al., 2007; Wall et al., 2017). The funding agency should support ex-ante evaluations to assess potential societal impacts, recognizing the importance of comprehensive and meaningful impact evaluation (Kny et al., 2023), and reporting substantial amount of preliminary data (Walter et al., 2007).

TDR evaluation is vital for documenting scientific and social impacts and addressing the needs of funders and other non-academic stakeholders (Belcher & Halliwell, 2021; Lang et al., 2012). However, it is difficult to assess ‘what works, how and why’, as there is a lack of accepted criteria to evaluate TDR (Belcher et al., 2016). Traditional approaches rely on academic metrics, i.e., citations of peer-reviewed journal articles, successful grants for career promotions and tenure

purposes, are insufficient to report social impact of the research (Owen, 2021). A broader evaluation approach and evaluator competencies to document potential impacts of TDR is needed. A robust toolkit and clear indicators are required to outline evaluators' prerequisite skills to effectively plan and execute the TDR evaluation. These skills are essential, especially when addressing complex, uncertain, interconnected, nonlinear, and emerging problems (Regeer et al., 2009). Evaluators liaison interactions between the researchers and practitioners by providing inside and outside perspectives and assessing research impact (Verwoerd et al., 2020). Therefore, to maximize the impact of research, we need flexible evaluative frameworks that can be applied by researchers and practitioners in diverse contexts (Holzer et al., 2018). The methodological principles advocate for collaborative evaluation, emphasizing stakeholder engagement, a well-articulated theory of change, diverse data collection methods, and consideration of tangible and intangible outcomes (Englund et al., 2022). While these principles stress evaluating research impact, they do not specify the competencies required to assess these impacts. Additionally, the academic community struggles to define and find ways to measure the social impact of the TDR process (Schäfer et al., 2021). Evaluation of the TDR often faces criticism for lacking a well-defined quality criterion (Belcher et al., 2016; Carew & Wickson, 2010; Jahn & Keil, 2015). The existing frameworks employed to evaluate the TDR are questioned for their limited application, lack of relevance to context, and adequacy to include various components of the TDR (van Drooge & Spaapen, 2022).

Evaluators' competencies and need for evaluation of TDR

Competence means a person possesses sufficient skills needed to perform duties in any given field (Stevahn et al., 2005). With reference to evaluating competencies, all the evaluation skills,

knowledge, ability, and qualifications could comprise evaluation competencies (Davies, 2021; McGuire and Zorzi, 2005). A clear understanding of the competencies is needed to standardize and identify who could be the evaluator. The rationale behind developing the competencies is to address the challenges related to the ambiguity of professional identity of the evaluators and ascertain their qualifications. The clear guidance on the competencies helps clarify what the evaluators should know. This clarity broadly benefits the evaluators in expanding the training, awareness of personal strengths and weaknesses, and credentialing evaluation in the field (Stevahn et al., 2005).

Previous research entails principles, guidelines, methods, frameworks, and indicators to understand and assess the TDR (Belcher & Halliwell, 2021; Carew & Wickson, 2010; Englund et al., 2022; Evely et al., 2010; Holzer et al., 2018, 2019; LaVelle & Dighe, 2020; O'Connor et al., 2019; Plummer et al., 2022; Steelman et al., 2021; Stokols et al., 2003; van Drooge & Spaapen, 2022; Verwoerd et al., 2020; Wall et al., 2017; Walter et al., 2007). A well-reputed competency framework of the American Evaluation Association (2018) is instrumental in guiding the evaluation of programs. The framework includes 49 evaluators' competencies in five domains such as professional practice, methodology, context, planning and implementation and interpersonal. Similarly, Canadian Evaluation Society presented 36 competencies in the domains of reflective, technical, situational, management and interpersonal practices (Canadian Evaluation Society, 2018). Undoubtedly, these competency frameworks are invaluable yet limited to evaluate dimensions of TDR. A community of evaluation experts is needed to conduct TDR evaluations considering TDR's broad and multi-dimensional scale (Wickson et al., 2006). Moreover, the evaluation competencies mentioned across the program evaluation are general; however, it is argued that there are specific skills related to evaluating the TDR as it is multi-dimensional and complex. Therefore, developing a list of competencies to comprehensively evaluate TDR pursuits is crucial. Research needs to be conducted to determine which programs can teach these skills,

how these skills could be stimulated, and which mediums could stimulate the transdisciplinary skills (Fam et al., 2017). The evaluations are very case-specific; however, in the parallel universe, concerns exist related to understanding the TDR itself but not the transdisciplinary evaluation.

However, there are no clear guidelines for transdisciplinary evaluators. Existing literature unfolds what should be measured, with what skills are not yet fully reported. Evaluators are trained with specific competencies needed for the specific problem context, but they may not be able to address the wicked problems. Our research aimed to narrow gaps by identifying and establishing core competencies that evaluators could confirm before engaging and evaluating TDR. While we acknowledge existing competency frameworks (e.g., American Evaluation Association, 2018; Canadian Evaluation Society, 2018; Stevahn et al., 2005), we argue that these competency frameworks lack specific competencies required to evaluate TDR programs. Finding transdisciplinary evaluators and reviewers poses a challenge due to a vacuum of clear guidelines on the acceptable standards for data collection and analysis (Selberg et al., 2021). Furthermore, the 'positionality' of evaluators within the evaluation process significantly impacts its effectiveness, a factor often overlooked in previous research, which primarily focuses on the evaluation process itself. We argue that without recognizing the pivotal roles, skills, and development opportunities for evaluators, achieving a truly transdisciplinary evaluation remains elusive. The researchers engaged with the TDR are not well versed with methodological approaches and diverse actors in the TDR and require capacity building in this direction (Kny et al., 2023). Numerous evaluative criteria for the TDR have been mentioned (Blackstock et al., 2007; Belcher et al., 2016; Carew & Wickson, 2010; Jahn & Keil, 2015; Walter et al., 2007; Wiek et al., 2012). These principles have emerged from the direct experiences and observations of the researchers lack a consensus on the set of evaluation competencies. Moreover, the absence of a community of expert peers for the quality evaluation also highlights the research gap (Wickson et al., 2006). To address this issue, it is crucial to define the skillset that

transdisciplinary evaluators should possess. This would enable more rigorous and systematic evaluation throughout and across the projects. Additionally, the evaluators are external to projects; the externality also inhibits their role in completely grasping various processes and impacts of TDR. Externality limits the capacity to apply a suitable criterion to appropriately measure the project quality (Regeer et al., 2009). Our research aims to build consensus on lived experiences and exposures to TDR situations. This research was to develop the competencies needed for evaluators engaged or interested in conducting TDR projects. The nature of TDR is to address a complex problem, where the evaluation of TDR assesses how effectively various research processes have been fruitful in addressing the problems. Therefore, the following research question guided the research: what core competencies are required by the evaluators for evaluating the TDR projects?

By answering this research question, the research seeks to build competencies and draw the attention of current and potential TDR evaluators. Moreover, university-based programs, including the program evaluation curriculum, may consider broadening these competencies as a part of training future evaluators. The current research is useful for capacity building, funding agencies, and evaluation field itself.

Methods

Study context

We conducted this study with a panel of evaluation experts evaluating the Agriculture and Food Research Initiative's Sustainable Agricultural Systems (SAS) program area. These programs were funded by the United States Department of Agriculture's National Institute of Food and Agriculture (USDA NIFA). The SAS program aimed to provide accessible agricultural

and food products and abundant economic opportunities for the public. These programs have TDR teams working at the intersection of education, research, and outreach and improving the sustainability of agricultural and food systems (*Agriculture and Food Research Initiative*, n.d.).

Given the breadth of the SAS programs addressing diverse agriculture sustainability issues. These projects were ideal for us to select a panel of experts for this research as these projects represent diversity in contextual conditions, researchers' expertise, type of stakeholders involved, research areas, and team dynamics. We intended to include a representative sample that is diverse, accessible, and TDR in nature. The evaluators in the SAS programs are suitable and offer a broad integration of disciplines and stakeholder groups and focus on assessing broad social, cultural, and economic impacts. Ideally, the SAS program met the research requirements and ensured the generalizability of findings across broader TDR contexts. For our current research, we wanted to capture the reflections and experiences of evaluators currently evaluating TDR programs. Therefore, we purposively created a panel of experts focused on the SAS projects across the United States only.

In each SAS project, there was at least one external evaluator whose role was to provide unbiased and regular evaluation for smooth functioning of the project. In these projects, the external evaluators were tasked with conducting various evaluation studies, including need assessment and formative and summative evaluation, to document and improve the research process, progress, and impact and help research teams achieve their objectives. The current study was the brainchild of one of the projects sanctioned under USDA NIFA's SAS grant program titled “Thriving Agricultural Systems in Urbanized Landscapes” (*Thriving Agricultural Systems in Urbanized Landscapes*, n.d.).

Delphi Panel

We formed a panel of TDR evaluators from all evaluators who were assessing the process and impact of the TDR project funded under the SAS funding portfolio of the USDA NIFA's AFRI funding program. The SAS project evaluators bring sufficient knowledge, experience, and expertise to reflect and support this research. Disciplinary expertise was a key consideration in recruiting a panel of experts (Hsu & Sandford, 2007). The external evaluators were considered appropriate as they were actively involved in evaluating research processes and reporting the impact across many complex issues.

We identified 41 SAS projects funded between 2019 and 2024 to recruit a representative panel of experts. From the funded project directories, we focused on external evaluators directly. They were targets for our research. To develop a complete list of evaluators, we contacted the Principal Investigators of SAS projects to obtain information about their external evaluators and developed the prospective panel for the study. Based on the available information, the expert panel was contacted with an initial email explaining the background and objectives, as well as a brief methodology to inform the prospective panelists about the significance of research to the evaluation field. It is also important to specify why evaluators work on evaluating TDR projects were important for this research because they possess a real treasure of lived experiences, challenges, opportunities, and reflections. The panel was formed by identifying and inviting individuals from diverse geographical regions (Fam et al., 2017). Further, we intentionally did not involve program evaluators responsible for evaluating traditional programs of interdisciplinary or multidisciplinary nature. We were cautioned that this might jeopardize the results and limit the knowledge to the traditional set of competencies that other scholars have already provided (American Evaluation Association, 2018; Diaz et al., 2020). Consequently, 26 experts out of 41 were agreed to participate in the research.

Delphi study design

A Delphi study was employed to gather input from a panel of experts in the field. The Delphi technique is valuable for seeking anonymous opinions from experts on a given topic (Dalkey & Helmer, 1963; Dalkey, 1972). Anonymity offers a comfortable space due to lack of social pressure from the other respondents (Geist, 2010; Mukherjee et al., 2015). The study used the modified three-phase Delphi method (Warner, 2014) (Fig. 1) to identify the competencies required for evaluating TDR programs (Kumar Chaudhary et al., 2020). The three rounds of study were conducted using online Qualtrics surveys from April to August 2024. The study was approved and conducted by adhering to the guidelines of the Institutional Review Board at The Pennsylvania State University.

We developed the first round of Delphi study using open-ended survey questions. We used a panel of six reviewers who were identified based on their expertise in TDR, evaluation methods, and survey development. Based on their suggestions and critique, appropriate changes were made to the first round open-ended research question. The survey was developed based on the suggestions of Dillman et al. (2014). For each round of Delphi study, 10 days were given to panelists to respond. The panelists were provided clear instructions on the survey for providing responses to avoid any confusion and misunderstanding. Before data collection, the survey was mock tested to ensure respondents could easily fill in the responses.

The first round of the study, i.e., the generative round, aimed to develop a list of competencies based on the reflections and experiences of the participants (Diaz et al., 2020). For this, we used a qualitative question to capture the core TDR evaluation competencies, "*Please list all the core Evaluation skills or competencies that are needed to conduct meaningful evaluations*

of the TDR projects." The qualitative question used a large response box size following the guidelines of Kumar Chaudhary and Israel (2016) to collect detailed and meaningful data. Open-ended questions are helpful when the subject is less unknown and exploration is nascent. Apart from the qualitative question, we used three quantitative questions to gauge panelists' experience, area of evaluation, and educational level.

We used constant comparative analysis method to analyze data from the first round's open-ended question. Typically, the constant comparison method offers development of a theory hidden from the responses. This process starts with reading through the raw data and attaching a raw code to each narrative to address the research question. Therefore, we coded and recoded the data on an Excel spreadsheet iteratively and compared the emerging themes constantly until crystal clear categories were derived (Glaser & Strauss, 1967; Lincoln & Guba, 1985). After multiple iterations and revisions based on discussion among two coders, with a 73.1% response rate (n = 19), a total of 83 competencies were identified after the first round, which covered a wide range of areas such as understanding the concept of the TDR, different modes of data collection, and following the ethical practices for the data collection. In the second round, these 83 competencies were again sent to 26 panelists, who were asked to rate the competencies on the five-point Likert scale (1=*strongly agree*, 2=*agree*, 3=*neither agree nor disagree*, 4=*disagree*, 5= *strongly disagree*). We also added an open-ended item for the panelists in the second round to allow them to add any competencies they felt were missing from the list. In the second round of data collection, *a priori* criteria was employed where the responses from two-thirds of panelists selecting *strongly agree* and *agree* were retained for the third round. In this round, the open-ended question to capture additional competencies added no new competencies but provided feedback to remove the double-barreled statements, such as conducting responsible and credible evaluations. This statement was revised into two statements a) conducts the responsible

evaluations, b) conducts the credible evaluations. Following *a priori* criteria, we retained 71 competencies at the end of the second round, with a 73.1% (n = 19) of response rate. The third round was a conclusive round, where the panelists were asked to provide feedback on the results of the second round and build consensus on the set of competencies (Hsu & Sandford, 2007). In the third and concluding round of the research, the 71 competencies from second round were again sent to the panel of experts who were asked to rate their responses on five-point continuum (1=*strongly agree*, 2=*agree*, 3=*neither agree nor disagree*, 4=*disagree*, 5=*strongly disagree*) to express their agreement or disagreement, whether these are competencies are eligible to form the final pool of competencies essential for evaluating the TDR projects. Consequently, following *a priori* method, we retained 60 competencies with a 65.4% (n=17) of response rate.

Comparison with American Evaluation Association Competencies

The American Evaluation Association (AEA) competency framework including 49 evaluation competencies is well-documented and well-received by researchers and evaluators (American Evaluation Association, 2018). To better understand and apply these 49 competencies in evaluation capacity-building efforts, AEA has classified these competencies into five domains, which are professional practice (i.e., evaluation standards, principles, and practices etc.), methodology (i.e., data collection methods quantitative, qualitative and mixed methods, etc.), context (i.e., stakeholders, historical factors, location, political, etc.), planning and managing (monitoring, networking), and interpersonal (e.g., conflict management skills, communication skills). To better situate our competencies with existing literature, we compared our newly identified competencies with five domains of AEA competencies using the approach suggested by Diaz et al. (2020) and Stevahn et al. (2005). Therefore, we understood the meaning of each competency and interpreted the nature of the application of these competencies. Following AEA

evaluation competency framework, each competency was matched with the corresponding category in the AEA framework to determine any discrepancy. We built consensus on the matching process, clarified the discrepancies with discussions, and determined the domain of each competency (Table 2). We realized that there were about 12 competencies that did not belong to these standard five domains. Based on their nature and scope of application, those competencies formed a new category, 'Unique to TDR'. These competencies are derived based on a fundamental understanding of the theoretical and practical orientation of the TDR in terms of relevance, usefulness, collaboration, and translating findings across different stakeholders. These competencies are required to effectively evaluate the TDR projects.

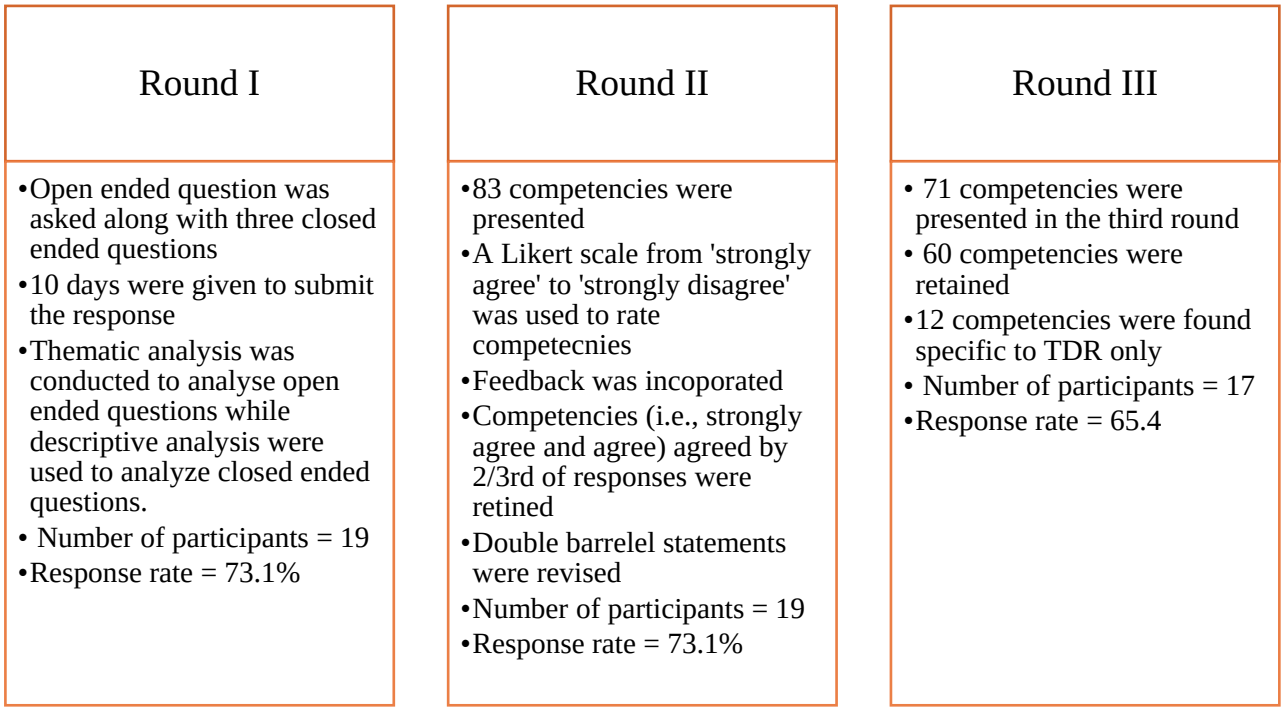

Figure 1: Detailed description of the Delphi study

Results

This section presents comprehensive findings from the Delphi study and a descriptive analysis of panelists' characteristics. In addition, these findings were compared with the American Evaluation Association (2018) competency framework to understand their alignment and identify novelty towards the TDR evaluation.

Descriptive analysis of characteristics of the panel of experts

Descriptive results showed that most panelists had doctoral degrees (84.2%) followed by a master's degree. Regarding experience, around one-third (31.6%) of the panelists had over 12 years of evaluation experience, followed by 26.3% with 7-9 years of evaluation experience. An equal proportion of respondents (15.8%) had 10-12 years and 4-6 years of experience, while 10.5% possessed 1-3 years of experience. The major areas of the evaluation of panelists represented expertise in a broad range of disciplines, including natural resource management, public health, and food safety. More specifically, the major subjects reported entailed agricultural conservation, climate science, environmental research, agroecology, public health evaluation, mental health, youth resilience, community health, food systems, and food safety.

Results of Delphi study

The Delphi study's final round (Table 1) yielded 60 competencies. A hundred percent consensus was observed for nine competencies for example, a) conducts the responsible evaluations (i.e., ethical conduct, fairness, stakeholder engagement, and accountability), b) conducts credible evaluations (i.e., methodological rigor, objectivity, and reliability of results), c)

links objectives, activities, measurements and outcomes, d) communicates clearly (e.g., jargon-free), e) applies professional evaluation standards to evaluations, f) respects evaluation stakeholders (e.g., clients, respondents, and program participants), g) conducts culturally responsive evaluation, h) ensures the relevancy of the findings to both academic and non-academic audiences, and i) ensures the usefulness of the findings to both academic and non-academic audiences. Our analysis showed that 94.1% consensus was achieved for 19 competencies, whereas 88.2% and 76.5% of agreement were achieved for 10 competencies each. Additionally, six competencies achieved a collective agreement of 70.6%.

Discussion

To ensure rigorous evaluation of TDR projects, this study aimed to identify and build essential competencies necessary for evaluating TDR projects. There is a wealth of literature focuses on the evaluation principles, methodology, and frameworks about TDR in general or particularly emphasizing stakeholder engagement and societal impacts (Belcher & Halliwell, 2021; Carew & Wickson, 2010; Englund et al., 2022; Evely et al., 2010; Holzer et al., 2018, 2019; LaVelle & Dighe, 2020; O'Connor et al., 2019; Plummer et al., 2022; Steelman et al., 2021; Stokols et al., 2003; van Drooge & Spaapen, 2022; Verwoerd et al., 2020; Wall et al., 2017; Walter et al., 2007). However, the current research builds a clear and simplified version of competencies for TDR evaluation. Moreover, our findings align with the methodological principles outlined by Englund et al. (2022). The principles emphasize engaging stakeholders in an adaptive learning process throughout the research. The principles also stress developing a theory of change, combining different data collection methods to address complex issues, and including tangible and intangible effects. However, the most obvious challenges in evaluation lie

in exhibiting the extent to which research has contributed (Kny et al., 2023). The evaluators are expected to have skills to report wide range of impacts. In addition to this, the study discovered contextual, political, and methodological challenges while engaging in evaluation (Quinlan et al., 2008).

Regarding agreement among the panelists, the study reported 100% consensus for the nine competencies (Table 1). The panelists reported that TDR evaluations need to be fair, ethical, accountable, and credible. The evaluators need to ensure that the findings are useful and relevant for academic and non-academic stakeholders. These findings draw attention to critical aspects such as context, methods, ethics, credibility, responsibility, and transfer of findings to wider audiences. It was reported that interconnection among objectives, activities, measurements, and outcomes is important. Success in understanding and documenting the interlay of these aspects makes it practical to report the changes taken place, deviation in findings from predetermined expectations, challenges faced while implementing, and possibilities for future improvements. Previous stresses on the societal impacts also emphasized connecting the outputs and outcomes by mediation effects of impacts (Walter et al., 2007). To capture the impacts of the TDR, understanding the interconnection of various actors, processes, and impacts is needed (Kny et al., 2023).

Professional practices incorporate distinctive features that enable evaluators to establish their unique identity (American Evaluation Association, 2018). In our study, we reported the willingness of the evaluators to expand their newer skills. By nature, TDR programs are diverse and unique. Therefore, replicating a similar evaluation approach might be insufficient; evaluators need to be open to learning new skills to adapt and align with the evaluation requirements.

Table 1

Results of the final round of Delphi study

	Statements	Two-Third 'participants' agreement
1.	Conducts the responsible evaluations (i.e., ethical conduct, fairness, stakeholder engagement, and accountability)	100
2.	Conducts credible evaluations (i.e., methodological rigor, objectivity, and reliability of results)	100
3.	Links objectives, activities, measurements and outcomes	100
4.	Communicates clearly (e.g., jargon free)	100
5.	Applies professional evaluation standards to evaluations	100
6.	Respects evaluation stakeholders (e.g., clients, respondents, and program participants)	100
7.	Conducts culturally responsive evaluation	100
8.	Ensures the relevancy of the findings to both academic and non-academic audiences	100
9.	Ensures the usefulness of the findings to both academic and non-academic audiences	100
10.	Opens to learn new skills	94.12
11.	Collaborates effectively in diverse teams	94.12

12.	Includes the participants belonging to diverse backgrounds (e.g., educational, cultural, social, historical)	94.12
13.	Functions effectively in diverse teams	94.12
14.	Respects the participants belonging to diverse backgrounds (e.g., educational, cultural, social, historical)	94.12
15.	Understands the programming cycle	94.12
16.	Follows best evaluation practices	94.12
17.	Understands and integrates diverse disciplinary perspectives	94.12
18.	Follows research ethics (e.g., protection of human subjects)	94.12
19.	Develops evaluation processes during the uncertain conditions	94.12
20.	Practices appropriate interpersonal skills (e.g., listening, relationship building)	94.12
21.	Knows how to solve problems	94.12
22.	Knows theory and practice of quantitative methods (e.g., epistemology, contextually relevant instrument design, data collection, data analysis)	94.12
23.	Applies context appropriate data collection methods	94.12
24.	Designs robust evaluations that can handle the complexity and variety of data	94.12
25.	Interprets and makes informed judgements	94.12
26.	Promotes use of evaluation results	94.12
27.	Knows the difference between short-term, medium-term, and long-term outcomes	94.12

28.	Practices systems thinking (i.e., ability to understand how does the small pieces of the research fits into larger context and their impacts)	94.12
29.	Practices effective personal skills (empathy, judgement, patience, and persistence)	88.24
30.	Able to meet various deadlines of the project	88.24
31.	Builds rapport with diverse project teams and partners	88.24
32.	Formulates actionable recommendations based on the evaluation results	88.24
33.	Knows the theory and practice of evaluation	88.24
34.	Implements appropriate evaluation strategies to engage diverse stakeholders, such as using participatory approaches	88.24
35.	Understands terminology used by the funders	88.24
36.	Demonstrates strong flexibility and adaptability in the dynamic nature of transdisciplinary research projects	88.24
37.	Knows theory and practice of qualitative methods (e.g., epistemology, contextually relevant instrument design, data collection, data analysis)	88.24
38.	Applies evaluative thinking	88.24
39.	Handles interdependent activities effectively	82.35
40.	Connects with project partners located at diverse geographical locations if needed	82.35
41.	Knows funding requirements	82.35

42.	Uses contextually appropriate data storage methods	82.35
43.	Ascertains validity and reliability of data collection methods	82.35
44.	Adapts to work across disciplines	82.35
45.	Understands theory and practice of transdisciplinary research	76.47
46.	Resolves the challenges related to evaluation of the transdisciplinary research projects (if any)	76.47
47.	Translates research findings for both academic and non-academic audiences	76.47
48.	Assesses implementation fidelity as appropriate	76.47
49.	Articulates theory of change	76.47
50.	Comprehends developmental evaluation methods	76.47
51.	Develops quality surveys for data collection	76.47
52.	Plans strategic evaluations	76.47
53.	Knows theory and practice of mixed methods (e.g., epistemology, contextually relevant instrument design, data collection, data analysis)	76.47
54.	Conducts quality surveys for data collection	76.47
55.	Remains unbiased towards project team and audiences	70.59
56.	Conducts outcome assessment	70.59
57.	Undertakes stakeholder analysis for identifying who are affected or will be affected by the research findings	70.59

58.	Identifies underlying values and motivations of project team members	70.59
59.	Provides rapid feedback during the changing contexts of the project	70.59
60.	Prioritizes and groups data evaluation requests to ensure efficient data collection while considering the impacts on participants	70.59

Additionally, evaluators need to be flexible and adept at positioning themselves by navigating the challenges related to diverse contexts and methodologies in large research projects (Quinlan et al., 2008). These competencies entail respecting and learning about research's educational, cultural, social, and historical aspects. Evaluators are required to adhere to ethical and cultural aspects in the evaluation process (Yarbrough et al., 2010). Given the diverse researchers and stakeholders and TDR's scientific and societal effects, evaluators need to understand and follow research ethics and apply evaluative thinking in TDR evaluation. Evaluators can apply evaluative thinking in their work before the start or while conducting the evaluation, and it has been emphasized that it should be learned (Cole, 2023).

We also aimed to compare and contrast the set of competencies with the American Evaluation Association competency framework categories. We identified new competencies in addition to existing categories in the American Evaluation Association competency framework. Our findings show that most of the competencies belonged to the methodology domain of the American Evaluation Association (2018). We identified similar and dissimilar competencies from the existing list of competencies. The newer set of competencies (Table 2) did not match the existing set of competencies (e.g., 2.3, 2.6, 2.7, 2.10, 2.15, 2.16, 2.19). These competencies signify evaluator's ability to assess how far the evaluation is faithful. For example, developmental evaluation requires evaluators to be able to evaluate in real time and adapt to changing dynamics. Moreover, the evaluators required technical knowledge to develop and conduct effective data collection and storage surveys and report outcomes, i.e., short, medium, and long terms.

In the case of the context, three competencies were new (e.g., 3.4, 3.5, 3.7). These competencies entail skills in the stakeholder analysis process and terminology the funders use. Moreover, managing data collection that practically focuses on operational aspects is imperative. Regular monitoring and evaluation to facilitate efficient research implementation and

incorporation of diverse disciplines is desired (Kny et al., 2023). Regarding planning and management, we identified '*knows funding requirements*'. This competency is essential in understanding the funding agency's expectations and requirements. Understanding funding requirements is important to tailor evaluation and predict alternatives if the required funding expectations are unmet. Moreover, the need for financial resources enables the decision on the scale of evaluation, time, and process to capture the different outcomes and impacts of the research.

The American Evaluation Association framework has five domains such as professional practice, methodology, context, planning and managing, and interpersonal. The classification (Table 2) resulted in a new category: we termed this competency category 'Unique to TDR'. Our analysis resulted in 12 competencies falling in the 'Unique to TDR' category. The crosswalk between the Delphi study and the AEA competency framework helped to determine the robustness of our findings and identify the novelty of our contribution to the scholarship of TDR evaluation. When the competencies were categorized following the American Evaluation Association (2018) Framework, it was found that most competencies fell into methodology (31.7%, n=19) followed by professional practice (15%, n= 9), context (13.3%, n=8), planning & management (10%, n=6) and interpersonal (10%, n=6). The newly formed category, 'Unique to TDR' contributed 20% of competencies to the overall competency pool. This category brings our attention to a wide area of competencies to understanding the theory and practice of TDR, addressing complex challenges, integrating diverse disciplinary perspectives, and ensuring the relevancy and usefulness of the findings to academic and non-academic audiences. These competencies reflect a wide range of conceptual and practical aspects of the TDR that evaluators need to hone. The category broadly captures the theoretical understanding of the TDR, which

Table 2

Categorization of the Evaluator competencies into the competency framework of the American Evaluation Association (2018)

Domains of the competencies	**Competencies**
Professional Practice	1.1 Opens to learn new skills
	1.2 Respects the participants belonging to diverse backgrounds (e.g., educational, cultural, social, historical)
	1.3 Conducts the responsible evaluations (i.e., ethical conduct, fairness, stakeholder engagement, and accountability)
	1.4 Follows best evaluation practices
	1.5 Applies professional evaluation standards to evaluations
	1.6 Follows research ethics (e.g., protection of human subjects)
	1.7 Knows the theory and practice of evaluation
	1.8 Knows how to solve problems
	1.9 Applies evaluative thinking
Methodology	2.1 Formulates actionable recommendations based on the evaluation results
	2.2 Conducts credible evaluations (i.e., methodological rigor, objectivity, and reliability of results)
	2.3 Assesses implementation fidelity as appropriate

	2.4 Links objectives, activities, measurements and outcomes
	2.5 Articulates theory of change
	2.6 Comprehends developmental evaluation methods
	2.7 Develops quality surveys for data collection
	2.8 Plans strategic evaluations
	2.9 Conducts culturally responsive evaluation
	2.10 Conducts outcome assessment
	2.11 Knows theory and practice of mixed methods (e.g., epistemology, contextually relevant instrument design, data collection, data analysis)
	2.12 Knows theory and practice of qualitative methods (e.g., epistemology, contextually relevant instrument design, data collection, data analysis)
	2.13 Knows theory and practice of quantitative methods (e.g., epistemology, contextually relevant instrument design, data collection, data analysis)
	2.14 Applies context appropriate data collection methods
	2.15 Conducts quality surveys for data collection
	2.16 Uses contextually appropriate data storage methods

	2.17 Interprets and makes informed judgements
	2.18 Ascertains validity and reliability of data collection methods
	2.19 Knows the difference between short-term, medium-term, and long-term outcomes
Context	3.1 Includes the participants belonging to diverse backgrounds (e.g., educational, cultural, social, historical)
	3.2 Respects evaluation stakeholders (e.g., clients, respondents, and program participants)
	3.3 Implements appropriate evaluation strategies to engage diverse stakeholders, such as using participatory approaches
	3.4 Undertakes stakeholder analysis for identifying who are affected or will be affected by the research findings
	3.5 Understands terminology used by the funders
	3.6 Provides rapid feedback during the changing contexts of the project
	3.7 Prioritizes and groups data evaluation requests to ensure efficient data collection while considering the impacts on participants
	3.8 Promotes use of evaluation results
Planning and Management	4.1 Able to meet various deadlines of the project
	4.2 Connects with project partners located at diverse geographical locations if needed
	4.3 Collaborates effectively in diverse teams
	4.4 Understands the programming cycle

	4.5 Develops evaluation processes during the uncertain conditions
	4.6 Knows funding requirements
Interpersonal	5.1 Builds rapport with diverse project teams and partners
	5.2 Functions effectively in diverse teams
	5.3 Communicates clearly (e.g., jargon free)
	5.4 Practices appropriate interpersonal skills (e.g., listening, relationship building)
	5.5 Handles interdependent activities effectively
	5.6 Identifies underlying values and motivations of project team members
Unique to TDR*	6.1 Understands theory and practice of transdisciplinary research
	6.2 Practices effective personal skills (empathy, judgement, patience, and persistence)
	6.3 Resolves the challenges related to evaluation of the transdisciplinary research projects (if any)
	6.4 Translates research findings for both academic and non-academic audiences
	6.5 Remains unbiased towards project team and audiences
	6.6 Understands and integrates diverse disciplinary perspectives
	6.7 Ensures the relevancy of the findings to both academic and non-academic audiences
	6.8 Ensures the usefulness of the findings to both academic and non-academic audiences

	6.9 Demonstrates strong flexibility and adaptability in the dynamic nature of transdisciplinary research projects
	6.10 Designs robust evaluations that can handle the complexity and variety of data
	6.11 Adapts to work across disciplines
	6.12 Practices systems thinking (i.e., ability to understand how does the small pieces of the research fits into larger context and their impacts)

These competencies don't align with existing framework of American Evaluation Association (2018) and are distinct for TDR evaluation.

includes principles, co-production of knowledge, complexity of problems, interdisciplinary nature, and stakeholder engagement and evaluation of these interconnected aspects. Apart from the scientific aspects of the TDR, the evaluators are expected to work with various researchers from diverse disciplinary expertise and stakeholders with varied interests, needs, and expectations of the TDR. Therefore, the evaluators are expected to ensure that the findings are relevant and useful for academic and non-academic stakeholders. It is advised that all potential stakeholders should be integrated at different stages of the evaluation to understand the program and outcomes (Quinlan et al., 2008). For this to happen, the researchers are expected to remain flexible and adaptable to meet the evolving needs and changes in the research process over time. Moreover, system thinking skills are also found important, which implies the evaluators' ability to understand how individual components are associated with the larger context of TDR. System thinking skills enable evaluators to understand how even small research contributions affect outputs, outcomes, and impacts over time.

Most of our identified competencies are central to the methodological section. Diaz et al. (2020) also observed a similar trend in their results while exploring the competencies in the context of non-formal educational program evaluation. They also observed a major concentration of competencies belonged to methodology (67%) domain of the American Evaluation Association competency framework (Diaz et al., 2020). Additionally, the crosswalk with AEA competencies enhanced credibility and robustness in scientific discourse. As a result, we not only identify competencies that align with the existing AEA framework but also expand upon them by introducing other competencies that are 'Unique to TDR'. This means that traditional program evaluators may assess their competencies and skillset and role to evaluate projects of TDR nature.

Since there are various ways to conduct evaluations, no single method can be used to train evaluators (Davies, 2021). These competencies draw the attention of capacity builders and

funders to support skill development. Moreover, these competencies could serve as a checklist to ensure that participating evaluators have essential competencies for effective evaluations of transdisciplinary programs. These competencies will facilitate comprehensive and sufficient training, promoting holistic skill development by considering essential programming skills (Diaz et al., 2020). Moreover, universities could include a TDR-based curriculum that addresses real-world issues (Evely et al., 2010). The competencies identified in our research could be used to develop evaluation curricula by educators to ensure quality evaluations (McGuire & Zorzi, 2005). These competencies streamline what needs to be included in training, workshops, or educational programs to strengthen the evaluation community. Further, these competencies serve as a self-assessment for the evaluators to decide on their professional development.

The study has implications for a broad range of stakeholders. Evaluators can use these competencies to determine whether they possess them or need more educational exposure for effectively evaluating TDR. Similarly, educators or program developers can integrate our findings in curriculum designs in skill or capacity-building programs. Although these findings emerged from the specific program (e.g., the SAS program), these competencies are applicable across various fields focusing on sustainability issues, public health and more. Funders can also support educators, program developers, and evaluators in this endeavor.

Nonetheless, we acknowledge that the study suffers from certain limitations. For example, the smaller size of the Delphi panel, which is 26 as opposed to 30 participants, which is considered optimum, is a limitation. However, as we focused on a single research initiative, finding the participants' consent to meet the threshold was inherently challenging. A recent study suggests 20-30 as an optimum size for Delphi studies (Manyara et al., 2024). Considering the commitment for three rounds and numerous ratings on the competencies is daunting. In this condition, research fatigue might have somewhat influenced the results (Geist, 2010). Future

research could be expanded to various TDR projects across different contexts and countries. The study could also be strengthened by studying the efficacy of the evaluators while using these competencies in evaluating their respective programs. At this stage, the competencies are developed, and more research is needed to test and determine the response of the evaluators, funders, and capacity-building programmers while putting these competencies into practice. Research using experimental survey methodology is needed, where the order of the questions is randomized. It is speculated that questions at the beginning might have received more attention than those at the end of the survey. The study could involve cross-cultural comparisons and longitudinal testing of these competencies to refine them further.

Conclusion and recommendations

The evaluation of TDR is required to assess its quality (Carew & Wickson, 2010). This study presents a consensus on the competencies identified by experts from the USDA NIFA AFRI initiative's SAS grant program. A total of 26 experts jointly contributed to identifying 60 competencies relevant to evaluating TDR through three rounds of Delphi methodology. The competencies identified in the research align with the AEA framework (2018) and offer a brand-new category of competencies 'Unique to TDR', especially in the case of TDR program evaluations, e.g., translating research findings for both academic and non-academic audiences and ensuring the relevancy of the findings to both academic and non-academic audiences. These competencies will be helpful to measure the ongoing programs and plan future TDR program evaluations. With the set of competencies identified, the researchers, funder, and evaluation capacity-building planners could reflect on their expectations and propose specific programs to strengthen existing capacity-building programs. From the capacity-building perspective, the study

stresses the need to consider the ‘Unique to TDR’ competencies while designing and implementing skill development training for evaluators interested in engaging in TDR evaluations. A strong emphasis on 'Unique to TDR' would enhance evaluators' effectiveness in reporting various potential impacts, e.g., at scientific, social, and policy levels. Future studies could aim to collect evidence of the newly added category, 'Unique to TDR’, on the evaluation efforts of the evaluators. Primary data collected from the evaluators would help validate, refine, or critique for future improvement in the scholarship of the TDR evaluation. Future studies could also capture the training needs of the evaluators for these competencies to narrow the gaps between what they know and want to know to improve their professional identity (Galport & Azzam, 2017). Future validating studies are expected to broaden the 'Unique to TDR’ section with additional competencies that might have been skipped in our study due to recruiting specific evaluators. Future studies inviting multi-stakeholders from various subject areas, where TDR is feasible and well-received, could be combined to advance the field of TDR evaluation.

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Appendix C: Delphi Study

Start of Block: Default Question Block

Transdisciplinary research involves both academic and non-academic stakeholders addressing complex problems relevant to science and society. The collaboration between academic and non-academic stakeholders occurs at different levels and in phases through multiple ways of information exchange in the research project. Thus, evaluating transdisciplinary research involves a critical understanding of the various activities, inputs, outcomes and impacts of the research by the evaluators. Therefore, we are interested in identifying competencies needed by evaluators for evaluating transdisciplinary research projects.

The participants are asked to participate in the three round Delphi study that focuses on building consensus on the competencies or skills needed for the evaluating the transdisciplinary research projects. The first round will include one-open ended question, where the participants will be asked to provide the list of competencies or skills needed for evaluating the transdisciplinary research projects. The second survey will ask the respondents to provide their level of agreement with the competencies or skills identified in the first round. In the third round, the participants will be given a shortened list of competencies based on the responses developed in the previous round and asked to carry out the same exercise. In total, each part of the study will take a maximum time of 30 minutes based on how much participants wanted to share, and a maximum total of 90 minutes for all three rounds.

Your participation is completely voluntary, and you may skip any questions during any rounds and exit the survey at any time. We will use adequate measures required by the applicable law to maintain the privacy interests of subjects and the confidentiality of the data. Your identity and the responses will be stored in a password-protected Penn State electronic database for the period required by applicable law and to the degree permitted by the technology used. Information collected in this project may be shared with other researchers, but we will not share any information that could identify you.

If you have questions, complaints, or concerns about the research, you should contact Parmveer Singh at pbs5513@psu.edu, or 402-617-4804 or Anil Kumar Chaudhary at auk259@psu.edu, or 814-863-7850. If you have questions regarding your rights as a research subject or concerns regarding your privacy, you may contact the Office for Research Protections at 814-865-1775.

By clicking (I agree/ I consent), you indicate that you understand and agree to The Pennsylvania State University's collection, use, storing and processing of your personal research information for the purposes described herein.

- ○ I agree/consent
- ○ I do not agree/consent

Please list all the core Evaluation skills or competencies that are needed to conduct meaningful evaluations of the transdisciplinary research projects.

_____

_____

Q3 How many years of program Evaluation experience do you have? (Please select the range that applies to you).

- ○ Less than one year
- ○ 1-3 years
- ○ 4-6 years
- ○ 7-9 years
- ○ 10-12 years
- ○ more than 12 years

Q4 Please check your highest level of education.

- ○ Bachelor's Degree
- ○ Master's Degree
- ○ Doctoral Degree
- ○ Other (please describe) _____

Q5 In your experience with program evaluation, which subject matter area, coupled with the core program evaluation methods, have you found most successful? (e.g., natural resource management program evaluation, early childhood education program evaluation)

_____

Chapter 5
Conclusion

Addressing complex environmental and societal challenges requires collaborative approaches that integrate perspectives from both academics and stakeholders (Jahn et al., 2012; Lang et al., 2012; Lawrence & Després, 2004; Pohl, 2011; Hoffman et al., 2017; Mauser et al., 2013). The multifaceted nature of issues seeks attention from diverse disciplines due to the broad impacts and implications of these challenges (Jahn & Keil, 2015; Klein, 2008; Max-Neef, 2005). To address such challenges, the TDR demonstrates significant potential to meet the growing contested issues and include stakeholders' perspectives (Wickson et al., 2006). In TDR, the roles of researchers are ever-changing rather than being stationary or identical throughout the process (Bulten et al., 2021; Hilger et al., 2018). Therefore, there has been some ambiguity around the role of researchers and stakeholders due to varied research processes, outcomes, and impacts. Hence, understanding how researchers view their positionality, TDR frameworks, and the overall success of TDR is important. Regarding positionality, Hakkarainen et al. (2023) examined the difference between ‘being’ and ‘doing’ sustainability research, which is interesting to understand the difference between TD researchers versus those who do TDR. Prior research has attempted to study the perspectives of the individual researchers working on the TDR (Augsburg, 2014; Boyle et al., 2023; Fam et al., 2017). Acknowledging the conceptual differences from other established research approaches, there is a need to establish a common grounding on the term TDR and its application across disciplines (Jahn & Keil, 2015; Lawless et al., 2024), which is an important inquiry needed to address these gaps. Hence, this research collectively explored the conceptual understanding and lived experiences of researchers engaged in TDR regarding various aspects of the TDR and TD researcher, motivations, advantages, and challenges; this was crucial for comprehensively examining theoretical perspectives and practical applications. Additionally, it was essential to understand how the stakeholder participation and co-production of knowledge

are conceived and applied in the TDR context. Considering the imperativeness of these aspects within TDR, we aimed to explore the link between theory and application and aimed to identify potential gaps, if there were any.

Despite the importance of TDR in addressing complex challenges, there is a need to develop criteria to assess its quality. Establishing criteria to maintain the research rigor emerges as a crucial need. Without such robust criteria, the evaluation of TDR may compromise the ability to estimate the quality of TDR (Carew & Wickson, 2010; Belcher et al., 2016). Consequently, this vacuum of quality criteria leaves the evaluators and funders to rely on the pre-existing disciplinary measures that do not align with the context of TDR (Belcher et al., 2016). Moreover, the community of peers who could review TDR quality is not established (Wickson et al., 2006), which indicates the need to develop skills and formalized approaches for evaluating TDR. In light of existing gaps and the current state of research, we aimed to understand the positionality of researchers in a transdisciplinary research project, i.e., the Thriving Agriculture Project, and build consensus on the evaluators' competencies for evaluating the TDR projects. The specific research questions guided this dissertation include:

1. To what extent do researchers' attributes (knowledge, motivations, advantages and challenges) affect the success of TDR?
2. What is the perception of researchers about stakeholder participation, co-production of knowledge, and their application?
3. What are the core competencies needed by transdisciplinary evaluators to evaluate the TDR projects?

By responding to these questions, the research contributed to explore the conceptual understanding of researchers about TDR and TD researchers, along with the exploration of motivations, advantages, and challenges faced while engaging in TDR. Further, the research seeks to address the questions related to stakeholder participation and co-production of

knowledge and application in the Thriving Agriculture Project. Lastly, the research aimed to identify and establish core competencies required by evaluators for evaluating TDR projects. This last chapter summarizes the findings of the three chapters: findings are presented to address three research questions, followed by the limitations, implications, and recommendations for future studies.

RQ1: Knowledge, motivations, advantages, and challenges to engage in TDR

Chapter II presented major findings related to the conceptual understanding of TDR and TD researcher and capturing motivations, advantages, and challenges while engaging in TDR projects. The research highlighted discrepancies in the conceptual clarity of researchers regarding the concepts of TDR and TD researcher. Our research identified a major knowledge gap among participants in articulately defining these concepts (i.e., TDR & TD researcher). The participants offered more interdisciplinary or multidisciplinary perspectives of the research than TDR, which infers that without a clear knowledge of what TDR involves, the effective application of these concepts is limited in designing and implementing the research processes. However, there are some aspects revealed by the participants for both TDR and TD researchers. In the case of TDR, it was learned that participants perceived TDR as a process of addressing complex challenges by integrating diverse disciplines and perspectives of researchers and stakeholders while acknowledging the role and influence of contextual factors. Based on the findings, we tried to connect different aspects mentioned in their descriptions to form a definition and were able to define TDR and TD researcher. We defined TDR as a process of addressing complex challenges by integrating diverse disciplines and perspectives of researchers and stakeholders by acknowledging the role and influence of contextual factors, while a TD researcher is a researcher who can conduct applied research by fostering collaborations across different disciplines and with

stakeholders by having a clear understanding of contextual factors and a personal drive to address complex issues.

Secondly, the investigation into motivations for engaging in the TDR revealed several interesting aspects. The participants mentioned that dealing with complex challenges, collaboration and networking opportunities, enhancing research skills, the nature of the project, and opportunities to engage with external stakeholders were some drivers for engaging in TDR. Interestingly, the study of how they benefitted from the engagement in the Thriving Agriculture Project revealed that the project helped them advance their research knowledge and skill sets, and professional outlook, receive institutional support, and collaborate across disciplines, institutions, and external stakeholders. Despite the benefits, the participants were constrained by difficulty understanding various facets of projects due to its large size and complex dynamics, interconnections with other teams, finding their own foci, anticipating TDR outcomes, time commitments, and logistical constraints (e.g., geographic locations). They mentioned that even though the project is targeting real-world complexity, the understanding and pacing up with different elements of the project sometimes gets overwhelming.

RQ2: Scientists' perceptions of stakeholder engagement and knowledge co-production in TDR

Chapter III discusses the findings related to stakeholder participation and co-production of knowledge and its application in the Thriving Agriculture Project. The key findings have been divided into two major themes: a) conceptual understanding and application of stakeholder participation, and b) conceptual understanding and application of co-production of knowledge. Regarding stakeholder participation, we reported a discrepancy in understanding of stakeholder participation and confusion with stakeholder engagement. Conversely, the findings captured

various expressions associated with stakeholder participation. Overall, the findings led us to conclude that stakeholder participation is an active and iterative collaborative process aimed at supporting the researchers with current happenings outside the academic silos. The stakeholders contribute to research by identifying and revising the research problems and study designs and further implementing research considering practical challenges and implications of the issues. More specifically, the researchers perceived that stakeholder participation is being utilized in the Thriving Agriculture Project by familiarizing the researchers with ground-level issues, tracking project progress, refining the research process, sharing outcomes, and seeking stakeholder feedback. The stakeholder participation provided satisfying experiences to researchers through engagement with diverse project stakeholders, against some exceptions where dissatisfaction was expressed. Most of the researchers intend to continue working with these stakeholders beyond the Thriving Agriculture Project, whereas, for some researchers, the collaborations with stakeholders depend upon factors such as availability of resources, alignment with stakeholders' interests in future projects, location, and scope of the project. It is worth mentioning that many researchers integrated their own stakeholders for this project with whom they have been working for a long time. They had established a clear understanding of needs, interests, mutual trust, and working relationships, which they envision to foster in future collaborations.

Before discussing the findings of the co-production of knowledge, it is important to differentiate how stakeholder participation and co-production are conceptually and empirically different. Stakeholder engagement involves multiple stakeholders collaborating on policy and decision-making aspects, whereas the co-production of knowledge broadly refers to co-developing science-based knowledge between stakeholders from academic and non-academic backgrounds (van Buuren et al., 2019). In this subsection of the research, the study aimed to report the conceptual understanding of the co-production of knowledge and perceived benefits for the research and stakeholders.

The findings showed a transparent knowledge gap; there was a lack of clear understanding and confusion about co-production with other approaches. Similarly, other colleagues mentioned that co-production is applied across various disciplines and contexts (Wyborn et al., 2019), but the meaning is not well-defined and needs further consideration (Bandola-Gill et al., 2023). In the case of exploring the conceptual understanding of co-production, two strands of findings were found. Firstly, it was found that there persists a lack of surety among the researchers about co-production. The need for a conceptual understanding of co-production and its application was felt (Voorberg et al., 2014). To the best of our understanding, there is also no practical guidance on how and when the co-production of knowledge is to be employed (Satterthwaite et al., 2024). Secondly, findings showed that researchers think the co-production of knowledge is a two-way process that allows the production and application of knowledge to address complex problems with the input of researchers and stakeholders. The findings are supported by (Satterthwaite et al., 2024), who conceptualized the co-production of knowledge in terms of co-designing the knowledge to address complex sustainability issues. The findings are aligned with Norström et al. (2020), who view co-production as the co-production of knowledge to build trust, foster collaborations, and understand the practical impacts of the research.

The research also explored the benefits of the co-production of knowledge for the researchers and stakeholders in the Thriving Agriculture Project. The perception of how the co-production of knowledge benefitted researchers and stakeholders was needed. The findings demonstrated that the researchers benefitted from ways such as enhancing their accountability of research for stakeholders, expanding horizons and stakeholder engagement, and improving the research findings for wider audiences. In the case of stakeholders, the researchers perceived that stakeholder also benefitted from advancing their networks with various stakeholders in other states, getting access to scientific information readily, freely, and in a format that suits their

ability to understand. Moreover, stakeholders benefitted from being aware of the latest research issues and opportunities. In a nutshell, it was reported that both stakeholders and researchers were perceived to benefit from mutual learning and continuous knowledge exchange through various interactions such as meetings, workshops, conferences, and beyond.

RQ3: Identifying core competencies required for evaluators to evaluate the TDR

Chapter IV aimed to advance TDR scholarship by identifying and establishing core competencies required for TDR evaluation. The research is based on three-round modified Delphi research. We formed a panel of 26 experts who contributed to this research through three rounds of data collection. The descriptive analysis of the data revealed a noteworthy diversity in the panel of experts' educational backgrounds, experience in evaluation, and field of evaluation (e.g., natural resource management, public health, and food safety). This would have strengthened our findings by collecting vast and rich data from the diverse panelists. The research based on three-round modified Delphi research resulted in 60 distinct competencies. It was also observed that 100% agreement was received for the nine competencies, which included: a) conducts responsible evaluations (i.e., ethical conduct, fairness, stakeholder engagement, and accountability), b) conducts credible evaluations (i.e., methodological rigor, objectivity, and reliability of results), c) links objectives, activities, measurements and outcomes, and applies professional evaluation standards to evaluations. Additionally, the research demonstrated that a consensus of 94.12% was achieved for 19 competencies, whereas 10 competencies received a consensus of 88.24% and 76.47%, respectively. Furthermore, six competencies achieved a consensus of 70.59%. A high degree of consensus among the experts for nine competencies exhibits the significance of these competencies to be acquired by evaluators for effectively practicing their evaluator role. Secondly, the research results are significantly related

to the American Evaluation Association competency framework. The American Evaluation Association competency framework is widely accepted and applied in diverse contexts to evaluate the effectiveness of programs. The AEA framework (2018) has five major domains: professional practice, methodology, context, planning and managing, and interpersonal. The AEA competencies are well suited to the needs of regular evaluators. However, these may not be suitable entirely for TDR evaluation as the TDR framework is wide and attempts to address complex problems and develop far-reaching impacts. Therefore, additional competencies were needed to meet the TDR's context, uniqueness, and complexity. We sought to identify the relatability of research results with the American Evaluation Association framework that helped to form a new category of competencies, i.e., 'Unique to TDR'. Of 60 competencies, 12 belonged to the 'Unique to TDR' category. Additionally, competencies were categorized following the AEA competency framework (2018), highlighting their respective concentration into each domain: Methodology (31.7%, n=19) followed by Professional Practice (15%, n= 9), Context (13.3%, n=8), Planning & Management (10%, n=6) and Interpersonal (10%, n=6). The 'Unique to TDR' had 12 competencies that contributed 20% of the overall competency pool. These competencies included a) understands theory and practice of transdisciplinary research, b) practices effective personal skills (empathy, judgement, patience, and persistence), c) resolves the challenges related to evaluation of the transdisciplinary research projects (if any), d) translates research findings for both academic and non-academic audiences, e) remains unbiased towards project team and audiences, f) understands and integrates diverse disciplinary perspectives, g) ensures the relevancy of the findings to both academic and non-academic audiences, h) ensures the usefulness of the findings to both academic and non-academic audiences, i) demonstrates strong flexibility and adaptability in the dynamic nature of transdisciplinary research projects, j) designs robust evaluations that can handle the complexity and variety of data, k) adapts to work

across disciplines and l) practices systems thinking (i.e., ability to understand how does the small pieces of the research fits into larger context and their impacts).

Implications of research

The study highlights the knowledge gap in researchers' understanding of components such as TDR, TD researcher, stakeholder participation, and co-production of knowledge. This gap reflects the need for fostering transdisciplinary education to equip researchers with essential skills to prepare for addressing sustainability challenges. Considering the significance of the TDR in addressing the complex challenges, the full potential of the researchers' expertise, institutional resources, and stakeholders' knowledge will likely be underused. Our research also highlighted challenges such as understanding our own positionality, the complexity of the large project, and the lack of conceptual clarity. Given the extensive learning opportunities that could support the training of both researchers and stakeholders, it has the potential to streamline research and potentially develop better working relationships, mutual trust, outputs, and impacts of the research.

Over the years, there has been a notable increase in publications on TDR, indicating that it addresses wide issues globally. Therefore, these findings are relevant and draw the attention of faculty and graduate students who are either engaged or would like to engage in the future. The theoretical preparedness of researchers is likely to enhance their effectiveness in navigating various stressors emerging due to their lack of knowledge and experience in TDR. The findings also call for university administrators to incorporate TDR education in existing academic structures. This could be done by promoting and supporting learning opportunities and encouraging researchers to take on transdisciplinary research. Here, we don't criticize interdisciplinary or multidisciplinary research approaches; those are well-known and have a long

history of evolution. In addition, we aim to expand the educational opportunities for faculty and graduate researchers who wish to learn and integrate diverse disciplines and various experts in the educational, governmental, non-profit, or general public sectors. These initiatives can help researchers form their TD researcher identity (Hakkarainen et al., 2023). Moreover, there is a need to incentivize and recognize TD researchers' efforts in career promotion programs. For example, stakeholder identification and engagement require considerable effort outside the university. These efforts require interpersonal competencies, adaptability, flexibility, along with scientific skills. The decision-makers at the university level need to pay attention to support such efforts and offer opportunities to gain these skills. Such efforts, undoubtedly, can encourage researchers to expand their disciplinary boundaries and collaborate with stakeholders to tackle complex environmental or social challenges.

Acknowledging the discrepancy in researchers' knowledge, it is unclear 'how much' uncertainty exists. Therefore, this qualitative study seeks to initiate dialogue on quantifying uncertainty, paving the way for more rigorous assessment and informed decision-making.

While stakeholder participation and co-production are core elements of the Thriving Agriculture Project, the researchers did not fully integrate them. This highlights the need for researchers to be better equipped with the methods, approaches, and frameworks of stakeholder participation and co-production to utilize these strategies effectively, justify allocating time and resources, and ensure accountability to stakeholders, funding agencies, and other relevant parties.

The perception of researchers failed to differentiate between stakeholder participation and co-production. A close observation of the findings revealed an immense overlap in the understanding of the co-production. However, these are distinct processes and have their epistemological stands. Both methods and the application of stakeholder participation and co-production are guided by their own theoretical frameworks. Therefore, it is likely that uncertainty about this confusion is likely to limit their application and capture the full-blown potential

benefits of TDR. The application of transdisciplinary research is continuously growing; it is highly suggested that researchers be equipped with different aspects of transdisciplinary research, for example, stakeholder identification, stakeholder engagement, and integration of scientific and social science research aspects to develop outputs and impacts. Clarity at conceptual levels is likely to enhance the transdisciplinary application and strengthen the positionality of the researchers. This will also mitigate the difficulties expressed by the researchers. Finally, the study emphasizes the need for capacity building (e.g., training, workshops, and practical experiences) to strengthen the capability of researchers to meet the emerging needs of sustainability challenges, funding agencies, and society at large (Lawrence et al., 2020).

The competencies developed (Chapter IV) are robust and diverse, yet application and testing in broader contexts of the transdisciplinary would help to know the first experience of the evaluators that will add more credibility, refinement, and critique. The study has positive potential to serve the variety of evaluators to use ‘out of box’ competencies and evaluate the programs with current competencies than traditional program evaluation, which poses challenges in terms of application in the TDR contexts. From the capacity-building perspective, the study stressed the need to consider the uniqueness of the TDR section in the education curriculum while designing and implementing the skill development training for the evaluators interested in engaging in TDR evaluations. In this direction, the funders can support the evaluators with resources and training that can help them gain skills for TDR evaluation, boost confidence and ability to assess the TDR process and impacts. Strong emphasis on this ‘Unique to TDR’ would enhance the effectiveness of evaluators to report various potential impacts, e.g., scientific, social, and policy levels.

The study has certain limitations that need to be acknowledged. Firstly, the study is based on the qualitative research design; there are no inferential statistics, which restricts understanding of the findings in quantitative terms (Tobias et al., 2019). Secondly, the small sample size of the

research study limits its generalizability, and findings have emerged from a single case study. To overcome the issues of generalizability, the study needed to be expanded to broader stakeholders and scientists (Thompson et al., 2017). Thirdly, data for Chapter II and Chapter III were collected simultaneously, and participants were requested to provide two-hour slots. In this research, research fatigue and disinterest could be latent variables that could have affected the depth of exploration and amount of information shared.

To contribute to the transdisciplinary research and evaluation research, future research could involve larger sample sizes, cross-comparisons, and longitudinal research design for deeper exploration of knowledge and application of concepts of transdisciplinary research, i.e., TDR, TD researcher, stakeholder participation, and co-production of knowledge. Moreover, these studies could also consider cross-comparisons across different projects to explore how stakeholder participation and co-production are perceived and practiced in different contexts. Identifying similar and dissimilar patterns would help refine and critique the definition and potentially develop new frameworks. This study relied on the researchers' perspectives of the co-production of knowledge benefits for them and their perception of the stakeholders' benefits. Future studies could include stakeholders' perspectives to gauge their satisfaction, perceived benefits, and future orientation to engage in projects addressing complex problems. Future studies inviting multi-stakeholders from various subject areas, where transdisciplinary research is feasible and well-received, could be combined to advance the field of transdisciplinary research evaluation.

Revisiting researcher positionality

My prior work experience has relied on multidisciplinary and interdisciplinary projects only. I had a very limited idea of TDR when I started this project. It was the first time I had heard of this term. The dissertation stemmed from my initial discussions with my advisor while

working on the communication framework for the Thriving Agriculture Project, where he introduced me to the world of sustainability science, transdisciplinary research, translational research, stakeholder analysis, and more. That was the turning point for me to incline toward the TDR. The Thriving Agriculture Project is an ideal example to experience TDR vividly. Further, reading literature on TDR exposed me to the world of TDR and broadened my vision of the interface of science and society and the possibilities of working in the TDR domain. It made me aware of the various concepts, such as TDR, wicked problems, positionality, and constraints of the researchers and stakeholders and beyond. It was a starting point for learning about TDR. However, my prior research and outreach have been largely involved with farmers. I also wanted to pursue doctoral research along the same lines. But destiny was more illuminating than what I had envisioned. Working on the Thriving Agriculture project allowed me to see not only the farming context but also the policy context.

Gradually, my interest in TDR started to rise. I continuously wondered how people with different educational backgrounds, research areas, and interests collaborate to solve a problem that has different implications for them. Moreover, how do researchers and stakeholders with varied expectations of roles and responsibilities work together? These initial ideas were further refined to address questions in my dissertation.

Moreover, I had not conducted any qualitative research in the past. Most of my research has been quantitative in nature. This was the first qualitative research I conducted, and it also included a variety of experts from different fields emphasizing the same phenomena. Admittedly, it was equally challenging and interesting, as I could see my position as a researcher was widening. It also challenged my position as a researcher, but I was supported with professional training received through courses I studied during my doctoral degree.

Working on the Thriving Agriculture Project has offered ample opportunities to learn about the practicalities of TDR. I was able to attend most of the workshops and meetings that

took place in different geographic locations and were online. These were illuminating for connecting with researchers working on the Thriving Agriculture Project. Moreover, I was privileged to attend national-level meetings and meet other researchers and external evaluators working on the different TDR projects throughout the United States. My interactions with researchers and evaluators contributed immensely to learning about the functioning of these projects, team dynamics, and aspects of education, outreach, and evaluations. These interactions undoubtedly laid a strong foundation in immersing myself and luminously connecting scientific literature to application. I acknowledge that my role as an insider in the project helped me contact the participants, despite the commitment to two hours for an interview constraining the findings to some extent.

With this dissertation, my interest in TDR has grown substantially. I aim to continue my research in the TDR space and attain a TD researcher identity.

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Appendix D:

Letter of correspondence from Institutional Review Board

PennState

Office for Research Protections
Human Research Protection Program
Office of The Senior Vice President for Research
The Pennsylvania State University
101 Technology Center
University Park, PA 16802

814-865-1775
irb-orp@psu.edu
research.psu.edu/irb

EXEMPTION DETERMINATION

Date: January 31, 2024

From: Samantha Bonaddio, IRB Analyst IV

To: Parmveer Singh

Type of Submission:	Initial Study
Title of Study:	Understanding Researchers' Positionality in Integrating and Designing the Transdisciplinary Research Process and Outcomes: A Case Study of Thriving Ag. Project
Principal Investigator:	Parmveer Singh
Study ID:	STUDY00024124
Submission ID:	STUDY00024124
Funding:	USDA National Institute of Food and Agriculture
Documents Approved:	• HRP_590_Interview Protocols_PS.docx (0.01), Category: Data Collection Instrument • HRP-591 - Parmveer Singh_PS_AKC_thirdRevision.pdf (0.04), Category: IRB Protocol • USDA AFRI SAS Project Narrative.pdf (0.01), Category: Sponsor Attachment

The Human Research Protection Program determined that the proposed activity, as described in the above-referenced submission, does not require formal IRB review because the research met the criteria for exempt research according to the policies of this institution and the provisions of applicable federal regulations.

Continuing Progress Reports are **not** required for exempt research. You must notify the IRB when the exempt research study is closed/completed by completing a continuing review in CATS IRB.

Changes to exempt research only need to be submitted to the Human Research Protection Program in limited circumstances described in the below-referenced Investigator Manual. If changes are being considered and there are questions about

VITA

Parmveer Singh

EDUCATION

2024 **PhD Agricultural and Extension Education,** The Pennsylvania State University (PSU),
2016 **M.S. Extension Education,** Punjab Agricultural University (PAU), India
2013 **B.S. Agriculture,** Punjabi University (PU), Patiala, India

SELCECT ACADEMIC PUBLICATIONS

Kumar Chaudhary, A., **Singh, P.,** & Basak, S. (2023). Understanding perceptions regarding how drinking water quality affects human and animal health among plain-sect community members. *The Journal of Amish and Plain Anabaptist Studies. 11*(2): 123-126

Alimoradi, Z., Majd, N. R., Broström, A., Tsang, H. W. H., **Singh, P.,** et al. (2022). Is alexithymia associated with sleep problems? A systematic review and meta-analysis. *Neuroscience & Biobehavioral Reviews*, *133*, 104513.

Kaur, P., Kumar, P., Gill, J. S., **Singh, P.,** & Singh, J. (2020). Popularization of chickpea and canola sarson for sustainable agriculture in Punjab. *Indian Journal of Economics & Development,16*(ss), 552-555

SELECT CONFERENCES (2024)

Singh, P. & Kumar-Chaudhary, A., (2024, April). *Interactive Communication: A Plausible Way to Bridge Gaps Between Science and Society through Transdisciplinary Research Environments. Paper presented at annual conference of Association for International Agricultural and Extension Education (AIAEE), Orlando, Florida.*

Singh, P. & Kumar-Chaudhary, A., (2024, April). *Perception of the [Watershed] Residents about the Sustainability of Agriculture in the Urbanized Landscapes.* Paper presented at annual conference of Association for International Agricultural and Extension Education (AIAEE), Orlando, Florida.

Singh, P. & Kumar-Chaudhary, A., (2024, April). *Application of the Health Belief Model to Understand the Intentions of the Plain Sect Populations to Adopt the Best Drinking Water Management Practices.* Paper presented at annual conference of Association for International Agricultural and Extension Education (AIAEE), Orlando, Florida.

AWARDS AND HONORS

2024 Dennis and Jimmie Findley Educational Enhancement Endowment, PSU
2024 Association for International Agricultural and Extension Education Scholarship
2024 CAS Graduate Student Travel Award, PSU
2024 Best poster presentation (2nd Prize), Gama Sigma Delta Research Expo, PSU
2023-24 M.E. John Applied Research Endowment Award, PSU

WORK EXPERIENCE

2018-2021 - Assistant Professor of Extension Education, Khalsa College Amritsar, India
2017-2018 – Senior Research Fellow, PAU, India
2016-2017 – Senior Research Fellow, SKUAST, Jammu, India