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Transdisciplinary Approaches for Market Intelligence Research: Theory, Practice, and Implications for Designing Product Profiles in Crop Breeding

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WORKIN PAPER November 2023

This research was carried out by ICARDA and enabled through fundings from the **CGIAR research initiative on market intelligence** and **CGIAR Gender Platform**. *We would like to thank all funders who supported this research through their contributions to the CGIAR Trust Fund.*

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Working Papers are one of ICARDA's global public goods; they capture and share knowledge and learning from projects and research partnerships. Each paper is internally reviewed as part of the Center's publishing process.

Suggested citation
Amoak, D., Najjar, D. 2023. Transdisciplinary Approaches for Market Intelligence Research: Theory, Practice, and Implications for Designing Product Profiles in Crop Breeding. Beirut, Lebanon: International Center for Agricultural Research in the Dry Areas (ICARDA).

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Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is a non-profit, CGIAR Research Center that focusses on delivering innovative solutions for sustainable agricultural development in the non-tropical dry areas of the developing world.

We provide innovative, science-based solutions to improve the livelihoods and resilience of resource-poor smallholder farmers. We do this through strategic partnerships, linking research to development, and capacity development, and by taking into account gender equality and the role of youth in transforming the non-tropical dry areas.

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ISSN 2709-7757
01423
9 772709 775008

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Introduction

Feeding the world's poor within sustainable limits remains one of the lingering global challenges that necessitate urgent attention (Intergovernmental Panel on Climate Change [IPCC], 2022). Addressing universal challenges such as food insecurity and climate change calls for wide-ranging perspectives and collaborative solutions at both international and global scales (McBean, 2021). Such a complex problem transcends geographical, cultural, and disciplinary boundaries, making it imperative for researchers, scientists, and development practitioners to draw upon a diverse array of expertise and knowledge from various disciplines (De Grandis & Efstathiou, 2016).

Transdisciplinary research (TDR), which hinges on knowledge co-production, context-specificity, pluralism, goal orientation, and interactivity (Norström et al., 2020), has gained traction in the last three decades in both science and policy and is increasingly deployed to address crucial challenges, including those in agri-food domains. This research lens captures the social, cultural, and biophysical complexities of agrarian environments (De Grandis & Efstathiou, 2016; von Wehrden et al., 2019). Academic and non-academic actors alike are essential to advancing this process, through the sharing of insights to improve methodologies and strategies.

Crop breeding is one area of research that has the potential to improve livelihoods and stimulate social change in the face of burgeoning climatic stressors (He & Li, 2020). Since the start of the 21st century, crop breeding has experienced remarkable transformations. Amid rising food insecurity and climate change, seeds well adapted to climatic stressors are seen as a pathway to climate resilience and development (Marimo et al., 2021). Many initiatives and programs corresponding to large-scale seed breeding have failed to include the needs, preferences, and selection criteria of women (Tarjem et al., 2023). The systematic exclusion of women and other minority voices may be linked in part to their limited representation in agri-food systems governance (Amoak et al., 2022), as well as programs bereft of research designs that embrace a plurality of views. Moreover, concerns arise that such a lack of diverse perspectives could cause "discourse inertia," whereby ideas become stale and constantly reproduced (Méndez et al., 2022), which in turn could hamper CGIAR's breeding targets[1].

The process of crop breeding produces differentiated understandings and impacts for different actors and players, which warrants a broad range of approaches to address the CGIAR impact areas. TDR, which involves scientists working in diverse teams with decision-makers, conservation groups, communities, and other stakeholders to address environmental concerns specific to a certain place, will be necessary to understand the needs of farmers while harnessing the strengths of a diverse pool of experts. Hence, this working paper seeks to analyze how the overarching knowledge-coproduction tenets of TDR could be implemented for more comprehensive seed-breeding initiatives that attend to the needs of all farmers, including women.

The goal of this strategic evidence review is to synthesize and analyze the literature on TDR approaches, with an emphasis on both theory and practice, including research design, team composition, and team dynamics to guide market intelligence research. We seek to highlight the theory behind how TDR works, state-of-the-art TDR project design, and implications for market intelligence TDR in crop breeding. The outcomes of this study add to the body of work seeking to define institutional norms for transdisciplinary teams in developing product profiles in breeding. The findings of this assessment will be valuable for research and development teams at the CGIAR and elsewhere working in agricultural and natural resource management.

Definition of terms

Transdisciplinary research

TDR transcends a research process to "encompass the institutional framework for the funding, organisation and dissemination of the outputs of transdisciplinary contributions especially when these are meant to address issues about sustainability" (Lawrence, 2015, p. 4). TDR is a means of addressing complicated issues or challenges by combining information, methodologies, and views from many fields. It goes beyond multidisciplinary research, which involves cross-disciplinary cooperation, by actively involving stakeholders and bridging the gap between academic knowledge and real-world applications. This knowledge production process recognizes that many real-world challenges are complicated and require holistic knowledge that a single field cannot provide. It promotes cooperation, communication, and knowledge co-creation among scholars, practitioners, policymakers, and other stakeholders to create innovative solutions to difficult social challenges. In recent

[1] CGIAR's five areas of impact are: Nutrition, Health, and Food Security; Poverty Reduction, Livelihoods, and Jobs; Gender Equality, Youth, and Social Inclusion; Climate Adaptation and Mitigation; and Environmental Health and Biodiversity.

times, the concept of transdisciplinarity has been used to identify research that incorporates non-academic partners (business, NGOs, public sector, civil society).

Market intelligence

In the context of CGIAR, market intelligence is the practice of gathering and analyzing data to identify and describe opportunities for breeding and seed systems to optimize their contribution to CGIAR Impact Areas of nutrition and health, poverty reduction, environmental health, gender equality and social inclusion, and climate adaptation (Donovan et al., 2022, p. 6). Doing market intelligence research "produces knowledge for business sectors from dispersed data and information for strategic market positioning, as an organizational continuum that aims to answer typical decision problems faced by firms when competing in actual business environments" (Jamil, 2013, p. 464). Hedin et al. (2014) explain that market intelligence research is made up of different market players with varying interests, together forming a composite working environment. These actors may be well-established industry players or mid-tier career folks or newcomers, with varying degrees of expertise. Apart from offering various business models and substituting products and services, certain market participants may pursue expansion through collaborations—either forward or backward integration within the value chain. Ultimately, interest groups also contribute to this dynamic landscape.

Product profiles

These are "the full set of targeted attributes, or the ideotype (plant model which is expected to yield a greater quantity or quality of grain, oil or other useful product when developed as a cultivar), that a new plant variety or animal breed is expected to meet to successfully be released onto a market segment" (Ashby & Polar, 2021, p. 2). Product profiles are considered the industry standard in commercial crop-breeding programs.

Research design

This is the overall strategy used to conduct research, involving a clear and coherent plan for answering well-defined research question(s) by acquiring, interpreting, analyzing, and discussing data. In crop breeding, demand-led validated product profiles and clearly defined breeding objectives play a crucial role in enhancing the efficiency of breeding efforts and inform the research design. These practices help determine the essential commercial values that are vital for local markets (KiMani, 2017).

Crop breeding

According to the National Institute of Food and Agriculture (n.d.), crop breeding is "the science of maximizing plants' positive genetic traits to produce desirable effects" (para. 1). Decades of advances in crop breeding have resulted in food availability, reduction in agricultural-related pollution, harnessing energy from agricultural practices, and food affordability. The aim of CGIAR for crop breeding is more strategic, efficient, and impactful. One approach to realizing this vision is the concept of gender-sensitive/intentional breeding programs, which have been heralded as useful in bridging the gender-gap by privileging the voices and preferences of women at all stages of the crop-breeding process. This process that brings together producers, farmers, and scientists has proven to be technically feasible and financially rewarding, and has become a leading government and community-based intervention in the livestock sector. Gender-sensitive breeding programs often focus on low-input systems and involve farmers within a specific geographic area who have a shared interest in improving the genetic resources of their livestock (Mueller et al., 2015).

Methodology

With the aim of providing a both a quick and broader overview of the literature on TDR for market intelligence research on crop breeding, this paper utilized a strategic evidence review approach. Strategic rapid reviews generally can be completed within a few weeks or months, making them a handy tool for decision-makers who need to act on the most recent information but lack the time for a more comprehensive review (Khangura et al., 2012). Furthermore, quick reviews give precise descriptions of the components of the research issue under consideration, as well as a robust and reproducible search method that highlights defined evidence selection criteria and quality judgments (Varker et al., 2015). These methodical stages and information not only illustrate the methodology's robustness, but also its high level of transparency, which strengthens the legitimacy of study conclusions.

Data for this evidence review were generated in three ways: (a) expert knowledge, such as working group members and pioneering researchers in the field of TDR; (b) database search of existing literature; and (c) a snowball search strategy involving reviewing the reference lists of related studies from relevant articles. The use of expert knowledge generated four working papers, including two market intelligence briefs. We used a multi-database retrieval approach, including Web of Science, Scopus, Google Scholar, and CGIAR research platforms to

retrieve both peer-reviewed and gray literature (materials or research produced outside traditional commercial or academic publishing and distribution channels). The search string used is provided in Appendix 1. Criteria for inclusion consisted of scholarly articles that specifically addressed TDR and studies that utilized transdisciplinary approaches as the foundation of their research. There were no geographical or time limitations due to the limited research on this topic; however, only studies published in English were included in this study. A total of 1,540 articles were retrieved, of which 46 were useful for this study. Lastly, we evaluated useful articles from the reference lists of relevant literature, and out for the 58 relevant studies identified, 14 were selected for this research.

Table 1: Search type and number of papers generated.

Search type	Number of papers retrieved	Number of articles utilized
Expert knowledge	6	6
Database search	1,540	46
Snowballing	58	14
Total	1,604	66

Findings 1: Theory and evolution

History of TDR

TDR is a compelling strategy that tackles complex societal problems by combining knowledge from different disciplines. Over time, TDR has grown and adapted, guided by various theoretical viewpoints and societal necessities. In this context, this paper delves into the history and theory of TDR, shedding light on crucial ideas and advancements that have molded its current path.

The roots of TDR can be traced back to the 1970s, when scholars like Erich Jantsch advocated for the integration of knowledge across different disciplines. Jantsch's work laid the foundation for the concept of TDR, which is seen as a way to address complex societal issues (Jantsch, 1972). In the 1990s, the idea of "Mode 2" science was introduced by Gibbons et al. (1994), which emphasized problem-oriented and interdisciplinary approaches to producing knowledge and stressed the importance of including diverse knowledge producers outside of academia. Funtowicz and Ravetz expanded on this discourse with their concept of "post normal science," a perspective that emphasized the assessment of solutions to complex problems at the intersection of science and policy. The authors called for new forms of communication about uncertainty and quality assessment, highlighting extended peer communities (Funtowicz & Ravetz, 1994a, 1994b). The concept of "wicked problems" was developed during this time as well and drew attention to the complexity, uncertainty, and conflicting perspectives associated with societal challenges. TDR emerged as a response to these wicked problems by acknowledging the limitations of traditional disciplinary approaches (Andersson & Törnberg, 2018). Concurrently, with the development of participatory governance practices came the shaping of TDR. The goal of these approaches was to involve stakeholders with diverse perspectives in analyzing problems collaboratively (Friend & Hickling, 2005). Participatory policymaking and governance initiatives were introduced with the aim to include stakeholders in decision-making processes while fostering collaboration among academia, government entities, industry representatives, and civil society (Friend & Hickling, 2005).

To further develop this field, Vermeulen and Witjes (2023) proposed a categorization system that divides TDR into three distinct types—intra academic, solution driven, and fairness driven—that describe the various levels of stakeholder involvement and foci found in TDR projects. As it is problem oriented and context specific, TDR is known for its flexibility in methods and approaches (Mitchell et al., 2015). Researchers employ a wide range of methods tailored to the specific research context, including problem structuring, systems analysis, solution search, and joint decision-making (Pohl et al., 2010). From its inception as a means to integrate knowledge across disciplines to its present-day focus on stakeholder engagement and problem-solving, the transdisciplinary approach to research has continually evolved. This type of research shows great promise as a tool for addressing complex societal challenges in the pursuit of sustainability and societal well-being, especially in the emerging notion of designing product profiles in crop breeding.

Epistemological underpinning of TDR (pluralist epistemology)

TDR at its core embraces a pluralist epistemology, which recognizes the existence of multiple valid ways of knowledge. By integrating these diverse perspectives, a deeper understanding of TDR can be achieved. Pluralist epistemology posits that knowledge and understanding can arise from various sources and perspectives, and acknowledges that different disciplines, cultural contexts, and forms of knowledge production offer valuable insights into complex phenomena (Frodeman, 2017). Klein (2010) suggests that pluralism entails accepting different legitimate ways of knowledge each with its own validity and limitations. This epistemological stance challenges the traditional positivist view that scientific knowledge is the sole form of valid knowledge.

The transdisciplinary approach to research embraces pluralist epistemology by recognizing that no single discipline or knowledge domain can fully grasp the complexity of real-world problems. Instead, TDR promotes the integration of diverse knowledge systems such as scientific, Indigenous, experiential, and local knowledge to achieve a more comprehensive understanding of the issues at hand (Klein et al., 2001). In applying this epistemological lens in designing product profiles in crop breeding, it becomes apparent that knowledge is rooted in the ways of knowing and should be recognized as a relational process and context specific. Thus, TDR seeks to promote collaboration and bridge disciplinary boundaries by recognizing and respecting multiple perspectives.

Pluralist epistemology, a key tenet of TDR, has several implications for its practice. Firstly, it emphasizes the active involvement of stakeholders with different expertise, cultural backgrounds, and knowledge systems. By working together, these diverse stakeholders can co-create knowledge and enhance our understanding of complex problems (Bammer, 2013). Secondly, pluralist epistemology challenges researchers to be introspective and acknowledge their own biases when integrating different knowledge systems. This self-awareness helps navigate potential conflicts and power dynamics involved in such collaborations. By creating spaces for dialogue and negotiation, researchers can foster inclusivity and equity in the research process (Jahn et al., 2012).

Furthermore, transdisciplinary researchers are encouraged by pluralist epistemology to embrace methodological diversity. This can be achieved by utilizing a combination of qualitative and quantitative methods, participatory approaches, and action research (Lang et al., 2012). By incorporating various ways of knowing into their work, researchers can obtain a more comprehensive understanding of complex problems. Pluralist epistemology serves as the foundation for TDR, which highlights the importance of integrating diverse perspectives, knowledge systems, and methods. By embracing pluralism, TDR recognizes the existence of multiple valid ways of acquiring knowledge and strives to promote collaborative knowledge production.

Types of TDR

TDR encompasses a range of approaches that seek to tackle complex societal challenges by incorporating knowledge from various disciplines and involving stakeholders. These approaches include participatory research, which emphasizes active engagement and collaboration with stakeholders throughout the research process (Hall, 1992). TDR recognizes the significance of local knowledge and strives to empower community members by involving them as equal partners in research initiatives (Cornwall & Jewkes, 1995). The goal of participatory research is to not only foster mutual learning and shared decision-making but also to achieve social change and address systemic inequalities (Wallerstein & Duran, 2006).

Another approach is community-based research (CBR), which focuses on actively involving communities in the research process to generate knowledge that meets their specific needs and aspirations. CBR projects prioritize collaboration between researchers and community members, acknowledging the importance of local context and the unique expertise that community members contribute (Minkler & Wallerstein, 2008). By foregrounding the voices and experiences of marginalized communities, CBR aims to promote social justice and equitable outcomes (Cargo & Mercer, 2008).

Still another approach under the umbrella of TDR is action research—a collaborative and iterative approach that combines research and action to address practical problems and bring about positive social change (Reason & Bradbury, 2008). In action research projects, researchers and practitioners work together to identify problems, develop interventions, implement changes, and reflect on outcomes (Kemmis & McTaggart, 2005). Action research emphasizes learning by doing and the co-creation of knowledge among researchers and practitioners (Stringer, 2014) and often involves cycles of planning, action, observation, and reflection to continuously refine interventions and strategies (Dick, 2014).

Although participatory research, community-based research, and action research share common goals of collaboration, empowerment, and social change, they differ in their specific emphases and methodologies: Participatory research focuses on involving stakeholders throughout the entire research process; community-based research places importance on community

involvement and context specific knowledge; action research emphasizes iterative cycles of action and reflection. These approaches are not mutually exclusive; researchers often combine elements from different types of TDR to fit the specific context and objectives of their study. Regardless of the approach chosen or combined elements used in TDR projects, all prioritize the inclusion of diverse perspectives and integration of multiple forms of knowledge.

Transdisciplinary monitoring, evaluation, and impact assessment

To effectively assess the impact of interventions, understand complex dynamics, and make evidence-based decisions, TDR requires robust monitoring, evaluation, and impact assessment. Monitoring involves the systematic collection, analysis, and interpretation of data to track the progress of TDR projects and initiatives. It encompasses both qualitative and quantitative methods to capture tangible and intangible outcomes. The focus is on understanding the processes, outputs, and outcomes of TDR to gain insights into the effectiveness of collaborative efforts, knowledge integration, and stakeholder engagement.

Additionally, evaluation plays a crucial role in assessing the quality, relevance, and sustainability of TDR projects. This involves a systematic and critical appraisal of the entire research process—from stakeholder engagement to research methods—to determine its contribution to knowledge generation and societal outcomes. Transdisciplinary evaluation emphasizes learning and adaptive management to improve future projects for maximum societal impacts.

Transdisciplinary impact assessment seeks to measure the wider effects and societal impacts of TDR (Nowotny, 2003). It goes beyond traditional academic measures and takes into account social, economic, cultural, and environmental dimensions (Kueffer et al., 2012). Transdisciplinary impact assessment assesses long-term and transformative change by evaluating how research has influenced policies, practices, and decision-making processes (Wiek et al., 2014). Participatory methods are often utilized to capture diverse stakeholder perspectives and incorporate local context (van Mierlo et al., 2010). Various frameworks and approaches have been developed to guide transdisciplinary monitoring, evaluation, and impact assessment. These include the Outcome Harvesting approach (Dart, 2005), the Social Learning Evaluation and Planning (SLEP) framework (Walter et al., 2007), as well as Contribution Analysis (Mayne et al., 2015). Additionally, structured methods like the Transdisciplinary Evaluation Framework (TEF) (Bammer et al., 2008) and the Impact Pathway Approach (Wiek et al., 2014) offer ways to evaluate and assess the impacts of TDR initiatives.

Transdisciplinary monitoring, evaluation, and impact assessment are essential components of TDR projects. These processes provide valuable insights into the effectiveness, relevance, and societal impacts of such initiatives.

Finding 2: Research design for TDR

Key considerations for designing TDR research

The TDR process has evolved over the past few years (Pohl et al., 2017) and basically attempts to link the two major areas of knowledge production: namely, societal and scientific domains. Societal issues are connected to sustainable development while the scientific process involves scientists designing and conducting research. Integral to TDR is that research questions should be framed to solve life and world pressing issues (Kueffer et al., 2007). This requires collaboration among scientists with heterogeneous knowledge. One of the major constraints about TDR is merging practice and science, mainly because scientists have different views of sustainability. Despite different approaches among various stakeholders of TDR, the common feature is that they all include academic and non-academic team members into the knowledge-generation process, ensuring relevance of research project to society. This requires adaptations in the research process. The science of sustainability is embedded in the complex relationship between humans and the environment (Brundiers et al., 2013). Sustainability refers to the attempt to satisfy the demands of the current generation whilst considering the demands of future generations (Brandt et al., 2013). Therefore, sustainability requires a transdisciplinary approach (Brandt et al., 2013). Needless to say, different disciplines have different perceptions mainly due to the wide array of methods used to generate evidence applicable to different fields. Unlike basic and applied research, which both draw research questions from scientific style of thought and practice, respectively, TDR utilizes a combination of both practice and scientific thought style (Pohl et al., 2017). The thought style entails a certain way of looking at the world, separating relevant from irrelevant (Pohl, 2011). From a disciplinary point of view, the thought style includes theories, methods, state of knowledge, quality criteria, and open questions. According to Moser (2016), some of the significant considerations for TDR include initiation, partner selection criteria and processes, type of engagement, and length and level of engagement. Nevertheless, the prime concern of TDR research is context (Carew & Wickson, 2010). Context is a necessary precondition for TDR because opportunities and

challenges are entrenched in rich contexts. Three aspects of context are widely recognized: problem-based context, research context, and researcher's context. Context also can be viewed through a social, political, and ecological lens (Norström et al., 2020). Context does not necessarily imply local; it can be regional or even global. The main emphasis of context-based co-production is the diversity in needs, interests, and beliefs representing a heterogeneous group of individuals affected by an issue. Indeed, context is defined according to a set of issues. The initial step to knowledge co-production is identifying policy entry points within a particular context to consider how TDR can help achieve goals and objectives of different partners involved. Furthermore, TDR requires plurality to ensure that those involved represent a wide array of skills and knowledge base (Norström et al., 2020). Moreover, co-production is enhanced by adding other dimensions of diversity including age, gender, and nationality. As such, having a more diverse teams ensures that multiple perspectives are considered on a particular issue. Kessel et al. (2008) emphasize three important points to consider when crossing disciplinary boundaries among scientists and other relevant stakeholders: First, one should consider the challenge of overcoming discipline rigidity; second, define the roles of various team members and stakeholders involved; and third, the team should define the problem or issue in a broad way.

How to design TDR teams

TDR is characterized by the inclusion of several disciplines, including stakeholders with different knowledge and expertise (Polk, 2014). The design of TDR can be conceptualized in three main phases (Pohl et al., 2017). Phase 1 involves linking the research question to the current knowledge base of the society and the society's need for a solution. Phase 2 includes identifying relevant disciplines and actors to be involved in the research project. Phase 3 comprises reflection, which involves identifying weaknesses and areas of improvement in the research project.

Project scope, data collection and analysis, gender, stakeholder engagement

Sustainable development requires a multisector collaboration involving multiple professions mainly into research and teaching (Brundiers et al., 2013). Stakeholder engagement is needed to ensure potential impact as well as societal relevance (Sagie & Orestein, 2022). Accordingly, stakeholders are defined as those who are affected or can impact the problem being addressed. The participation of stakeholders in projects is considered the cornerstone of democracy in modern society. The first step in stakeholder participation involves identifying stakeholders either through snowballing or stakeholder analysis. Stakeholder analysis is a method of identifying relevant actors and learning their behaviors and interests and their influence on the decision-making process. In addition, stakeholder analysis helps to empower marginal groups of stakeholders and eventually prevents conflicts. Data related to stakeholders can be collected through focus group discussions, interviews, and workshops. Specifically, stakeholder workshops are designed to gather a variety of perspectives, including fostering dialogue, thereby enhancing interactions. Focus groups are applicable when the issues are unknown or not understood by the researchers. And interviews are used to gather knowledge and experiences from actors. During interviews, each actor is asked questions to ascertain which aspects are relevant to them (Holzer et al., 2019). This method is entrenched in qualitative research methods, involves open questions with no predetermined hypotheses and is embedded in grounded theory. Thus, interviews offer a valuable method of data collection for complex issues such as the decision-making process during TDR.

TDR emphasizes the need for researchers to consider their work within a broader context by linking it to other disciplines and societal actors. Ideally, this involves identifying the interaction pathways among actors. Stakeholders can interact during knowledge co-production by informing, consulting, and co-producing (Pohl et al., 2017). To uphold an adapted interaction format, several questions should be considered regarding the societal actors and disciplines. Some of the pertinent questions include: Who participates in the project, and why? What issue is being discussed, when and by which method? Moreover, interaction in TDR could be normative, substantive, or instrumental. High-quality interaction among participants can result in ongoing learning among participants and helps to build trust through dialogue (Norström et al., 2020). To achieve this, TDR requires frequent interaction and should avoid passive participation as well as one-way communication. Ideally, bringing different expertise together and coordinating interactions is not enough; what is needed is mediation to decide what could and should be done (Klein, 2004).

Best practices for TDR

Best practices are needed if science and society are to reap a great benefit from TDR (Steger et al., 2021). The framework for best TDR practices focuses of five key areas: reflexivity, inclusion, integration, collaboration, and usability (Polk, 2014). Reflexivity is closely related to the concept of mutual learning which enables stakeholders and scientists to acquire knowledge whilst problem solving (Jahn et al., 2012). Besides multiple disciplines and diverse expertise, TDR practices require the following set of skills as a prerequisite: leadership, teamwork, facilitation, and an

ability to synthesize data and knowledge (Holzer et al., 2019). Collaboration in TDR is dependent on the members who are integral to the TDR process (Kessel et al., 2008). Among others, team members need to show commitment by ensuring enough time is allocated to the process. In addition, they need to ensure they are open to learn other disciplinary jargons and have the capacity and skills to build confidence and trust. Furthermore, team members need to practice equality by not prioritizing a particular discipline or knowledge domain. Bunders et al. (2010) suggest that the best TDR approach involves two major considerations, including the degree of knowledge input by lay groups and the existence of non-dominant groups in the decision-making process. Furthermore, Bunders et al. argue that the practice of TDR includes solving real-world issues and includes aspects such as grasping the complexity of an issue, taking into account diverse perspectives related to the issue, and connecting abstract concepts and specific findings on the ground. Lastly, the practice involves developing a knowledge base and practical methods that mirror the common good. Furthermore, Bunders et al. propose shared principles from TDR comprising elements such as joint efforts, joint problem definition, method-based analysis, mutual learning, and robust orientations.

Another best practice of TDR involves the selection of members of the transdisciplinary team. Consideration should be given to gender and participants active in practice-based research and content areas, including different stages of career development (Fam et al., 2016). In addition, the transdisciplinary team members should possess a set of TDR dispositions such as awareness, communication, curiosity, commitment, readiness, connectedness, and creativity (Fam et al., 2016). Advocates of the transdisciplinary approach claim that the following are the underpinning of the research process: learning to know, learning to do, learning to be with, and learning to be. "Learning to know" involves questioning assumptions and "learning to do" means acquiring a profession within a profession by linking together competencies that create a flexible inner persona. "Learning to be with" means assuming a new attitude that helps us examine our own convictions and finally "learning to be" is just discovering how we have been conditioned; that is, reflecting on the conflicts between the inner self and the social world (McGregor, 2004).

Reaching "consensus" in TDR

The management of diverse issues and public concerns by multiple experts raise a lot of conflicting issues, such as whose knowledge should be recognized, translated, and incorporated into action plans (Nowotny, 2003). TDR scientists are forced to answer questions beyond their competence unlike in disciplinary research. Thus, tension can arise among experts stemming from an epistemological, political, and institutional level. Hence, in modern society there is no safe way to make decisions considering the different expertise available. To reduce conflicts among several participants involved, TDR encourages the use of a step-wise participation approach (Norström et al., 2020). In addition, members of the TDR team should agree beforehand the measures of success. Focus groups can be used to elicit feedback on findings from data collected through interviews to inform a collective decision (Holzer et al., 2019). Reaching a consensus among actors in TDR involves identifying appropriate options from the range of available techniques (Newton & Elliot, 2016). It is imperative to match the recommendations with the purpose and what any action might deliver, including its possible constraining factors. To reach a consensus, each member of the TDR team is invited to make a contribution towards an element of the project for which they have expertise, or they may be asked to review the part related to their area of specialization. In addition, TDR teams can reach a consensus by brainstorming and discussing coupled with open, respectful, and ongoing communication among members to help build confidence and mutual trust (Wada et al., 2020). Needless to say, a sense of connection and comfort is necessary for a teamwork approach. Still, others argue that scientific intervention should not aim for consensus on problems and goals among actors to allow for the emergence of heterogeneous perspectives, and how that relates to scientific perspectives should be tailored through a second-order research process (Alrøe & Noe, 2010). The process is based on contextual communication reflecting second-order observations.

Case study examples to highlight the TDR research process

A majority of TDR processes are driven by researchers located in scientific and research institutions. In general, the TDR process involves three stages: formulation, generating, and evaluation (Polk, 2014). Carew and Wilson (2012) graphically illustrate these stages using what they call a transdisciplinary wheel (TDW). The wheel includes three stages—shaping (planning and proposing research), supporting (guiding), and evaluating—and emphasizes the three important elements of TDR, namely context, process, and product. The TDR process is best described as iterative, cyclical, contextual, and synergistic (Holzer et al., 2019). Researchers postulate that change in current agricultural practices is needed to curb the issue of environmental degradation. Based on the premise that current agricultural practices such as synthetic herbicides are a major contributing factor to soil degradation and a threat to environmental

conservation efforts, Teschner and Orenstein (2021) engaged in a problem-oriented study aimed at assessing the replacement of herbicides with the use of cover crops and mowing using specialized machines through agroecological transitions. Agroecological transitions are defined as man-induced change efforts aimed at efficiency, effectiveness, self-sufficiency, and affordability, including the inclusiveness of agro-ecological systems while reducing pressure and impact on natural surroundings. A major constraint in ensuring sustainability in agricultural practices lies in the complex nature of the food and production system, which cuts across the food energy and water triage. The transdisciplinary project consisted of social scientists and ecologists who were involved in initiating, developing, and sustaining better agroecological practices. The study was characterized by collaboration and integration including reflexivity, and an iterative process involving continuous analysis of results and inclusion of civil society. Three groups emerged from this collaboration, including winemakers, farmers, and scientists. The farmers were involved in the research process through interviews embedded in qualitative research that was coupled with ecological monitoring. The integrated study was conducted for 2 years. TDR was instrumental in this agroecological transition by providing a platform for communication among stakeholders thereby building trust among various actors. Thus, it provided a more holistic view of the agroecological transition process by ensuring that the change was beneficial to the system and carried out in a sustainable manner.

In Israel, Sagie and Orenstein (2022) employed a transdisciplinary approach to ensure the integration of various stakeholders in an ecosystem assessment at Mount Carmel Biosphere Reserve. This approach is in line with the goal of biosphere reserves to increase collaboration between scientists and local stakeholders. Biosphere reserves are a model of community-based sustainable use of natural resources. The Mount Carmel Biosphere Reserve was established by UNESCO as a natural heritage site to conserve the natural environment. The reserve is characterized by ecological and demographic variability, which has made management of the reserve problematic. Initially, different agencies including local councils and the military were the only stakeholders involved in the management of the biosphere reserve. For a long time, the reserve has yet to adopt a framework for sustainable management mainly due to the exclusion of community members in management issues involving the reserve. For instance, the reserve is constantly catching fire, which threatens the landscape of the entire area. Ecosystem assessment is a technique of relaying messages and demonstrating through action the significance of conserving nature and biodiversity as it relates to humans. The tool was designed to garner a wide variety of knowledge related to sustainable land management options Globally, land use practices have depleted the planet's resources, weakening the capacity of the ecosystem to provide humans with goods and services. The task involved three steps: stakeholder identification, stakeholder engagement, and communicating results in various stakeholder workshops. Specifically, the project involves three phases comprising stakeholder analysis, which was accompanied by semi-structured interviews; focus group discussion; and stakeholder workshops to allow for the discussion of the results. The approach revealed that TDR was critical for reviving the biosphere reserve using a neutral scientific discourse. Furthermore, it allowed for a discussion and engagement among different stakeholders who agreed on several possible ideas creating room for future collaborations. In addition, the project reflects a sense of ownership among the stakeholders involved. The study concluded that TDR is key in strengthening partnerships among academic and non-academic players (including local stakeholders) by disregarding their disagreements and using their diversity to create sustainable solutions.

Semi-arid regions face enormous climate change effects such as changing temperature, crop vulnerability to pests, and soil degradation, and in the semi-arid intermountain Pacific Northwest, the USAID-funded project employed a transdisciplinary approach to ensuring sustainable farming in the rain-fed cereal systems against the effects of climate change (Eigenbrode et al., 2018). The project utilized transdisciplinary research, education, and outreach. The 7-year-long project aimed at producing harmonized knowledge, including identifying techniques for improving efficiency and sustainability, besides farmer participation, educating producers and citizens, and providing decision support tools. The project involved educators and researchers from across the globe charged with a mission of transdisciplinary collaboration. Participants from across different continents have agreed there is a dire need for collaborative efforts in supporting vulnerable cereal production systems, especially in disadvantaged areas such as semi-arid regions. Further, the project recommends that the improvement of cereal systems should consider this inclusive approach.

In Colombia, the ÓMICAS project employs a multi-disciplinary research plan involving basic science, design, and implementation embedded in technological innovations aimed at improving agricultural productivity and food security (Jaramillo-Botero et al., 2022). The program combines theory, lab, field, and

computational experiments that enable the breeding and identification of new and improved varieties. The participants in this project include experts from different academic institutions across the globe. The project focuses on improving the overall environmental footprint caused by agriculture by breeding new varieties and creating new tools that promote efficiency and sustainable agricultural practices. The ÓMICAS project suggests that the TDR approach is a prerequisite for transferring genomic information into functional plant breeding both at the molecular and the microscopic levels. Furthermore, the study revealed that the TDR approach can save time and costs in experimental breeding and selection.

A transdisciplinary approach is key to mitigating and transforming agriculture climate change. Another excellent example of a transdisciplinary network is the direct-seeded rice consortium, a public-private multi-stakeholder research platform that aims to solve complex development issues in Asia (Helllin et al., 2020). In addition, it seeks to achieve economic and environmental sustainability of rice production by bringing together researchers and public and private partners from across South and East Asia. The project has proved that this approach results in an effective and viable alternative to rice production since the holistic approach allows for consideration of diverse issues that affect the system, notably water scarcity and rising labor costs.

A team of researchers took an approach to enhance barley varieties that align with local farming practices (Wenzl et al., 2004). By working with farmers and local agricultural experts, the team identified traits required for successful barley cultivation in the region. Employing a TDR process, the research team merged data on barley genetics with traditional farming techniques deeply rooted in Indigenous knowledge. As a result, they developed barley varieties that demonstrated increased resilience against pests, diseases, and drought while also preserving the heritage of the community. To address food security challenges in Sub Saharan Africa, researchers adopted an approach to maize breeding (Haile et al., 2019). In this endeavor, the research team actively involved farmers in selecting maize breeding candidates based both on information and visual evaluations. Through this breeding method, farmers successfully identified maize varieties that exhibited yields, improved resistance to diseases, and better adaptation to the region's specific climatic conditions. By empowering farmers to play a role in developing enhanced maize varieties tailored to their needs and environments, this transdisciplinary approach showcased its effectiveness.

In Ethiopia, a team of experts from various fields came together to create a livestock breeding program that involved the community (Getachew et al., 2020). They worked closely with livestock keepers to determine the desired traits for goats, such as growth rate and increased survival rates for their offspring. By combining data with the observations of farmers, the researchers succeeded in improving the characteristics of goats in that area. This collaborative approach not only boosted productivity in livestock but also empowered farmers to actively contribute to sustainable breeding practices.

A case study from South Asia involved researchers who used a TDR approach to develop wheat varieties that could thrive under adverse environmental conditions (Pohl et al., 2008). They integrated knowledge from disciplines like agronomy, genetics, and climate science to identify traits associated with yield and stress tolerance. Through collaboration with farmers, they tested these developed wheat varieties across agroecological regions. This interdisciplinary method helped identify wheat varieties that can withstand climate change impacts, ultimately benefiting small-scale farmers in the region.

In another case study, researchers in Latin America took on the challenge of improving potato breeding using the TDR approach (Ashby & Polar, 2021). They worked closely with farmers and experts from fields to determine which traits were most important for potato cultivation. By combining data with knowledge about traditional potato varieties, they successfully developed new and improved potato strains that showed greater resistance to pests and diseases. This breakthrough allowed them to distribute these disease-resistant varieties to small-scale farmers, resulting in increased yields and increased income levels.

Finding 3: Team composition

The importance of team composition (roles, dynamics, critical expertise, methodological expertise)

TDR is gaining recognition as an approach that is well equipped to address sustainability challenges, especially in fields like crop breeding and community-based livestock breeding programs (CBBPs). To achieve this, the significance of team composition must be shown. The success of any research relies heavily on team composition. By involving scientists, practitioners, stakeholders, and local community members from various disciplines and sectors, a collaborative and inclusive environment can be fostered (Pohl et al., 2008). Each member of

the team brings their expertise, perspectives, and skills to contribute to problem solving and knowledge generation.

A well-structured team consists of individuals with distinct roles. Scientists contribute their knowledge and research expertise while practitioners and stakeholders offer insights into real-world challenges and needs. In the case of CBBPs, local communities also play a role in preserving knowledge and contributing to decision-making processes. Consequently, successful TDR depends on collaboration and communication. It is crucial for team members to establish a shared language and understanding as this promotes knowledge exchange and reduces the chances of misunderstandings (Stokols et al., 2008). By engaging in discussions and reflexive meetings and negotiations, conflicts can be avoided or resolved and mutual learning can take place. The dynamics within a team also have an impact on problem-solving processes. When individuals with different perspectives and areas of expertise come together, they contribute to a comprehensive problem definition and analysis. Moreover, transdisciplinary teams are better equipped to identify solutions that consider economic and environmental aspects (Wiek et al., 2012).

In addition, TDR requires the involvement of experts from varied disciplines and with different backgrounds. In the field of crop breeding, collaboration among professionals specializing in genetics, ecology, agronomy, and social sciences is essential to develop resilient crop varieties. The presence of expertise ensures that problems are framed comprehensively and enables the team to address challenges from multiple perspectives. Furthermore, involving practitioners and local stakeholders in the team enhances the relevance and practicality of research outcomes (Haile et al., 2019). Farmers rely on their understanding of the environment, their crop preferences, and their expertise in breeding practices to identify traits that align with their needs and enhance crop performance. Expertise in research methods is also vital for studies. The integration of approaches and the development of new research methods facilitate effective learning at the intersection of science and society (Wenzl et al., 2004). Methodological expertise ensures that data collection, analysis, and interpretation are thorough and aligned with the research objectives. Furthermore, an integrated methodology allows for the amalgamation of knowledge systems, such as scientific knowledge and Indigenous knowledge (Schäfer et al., 2021). For example, successful livestock breeding programs like CBBPs rely on combining data with farmers' visual assessments to make accurate breeding decisions (Haile et al., 2018). In sum, team composition plays a vital role in research.

Strategies for building and coordinating effective TDR teams

Team building techniques

TDR teams play a crucial role in addressing complex sustainability challenges across various fields like crop breeding and community-based livestock breeding programs (CBBPs), and strategies are needed to build and coordinate such teams. Inclusive Stakeholder Identification forms the initial step in building a TDR team. It involves identifying stakeholders and individuals from varied disciplines, sectors, and communities. By utilizing stakeholder analysis and snowballing techniques, relevant actors with an interest in the research topic can be identified. This inclusive approach ensures that the team benefits from disparate perspectives, knowledge, and expertise, thereby enriching the research process. Each team member should then be assigned roles and responsibilities based on their expertise and contributions towards achieving the research objectives. Scientists, practitioners, and stakeholders all bring skills to the table within the team framework. Having defined roles helps minimize overlap or confusion among members while facilitating collaboration. Selecting a team leader who can promote collaboration, resolve conflicts, and encourage cooperation is crucial; however, it is important to be cautious about giving one person power and to avoid creating a "tribal" atmosphere within the team (U.S. Geological Survey [USGS], 2007). A strong team leader can guide the team through challenges and steer them towards outcomes. Effective collaboration requires preparation and practice. Team members should be aware of challenges and conflicts that may arise during the research process. Engaging in activities like team-building exercises, off-site retreats, and communication workshops can enhance collaboration skills and strengthen team dynamics. One important technique for building a team is establishing a unified language among its members. This can be achieved through discussions, reflective meetings, and collaborative problem-solving sessions (Stokols et al., 2008). When everyone shares a language, it promotes communication and knowledge exchange. Building trust and fostering communication are also vital, for collaboration. Creating an environment in which team members feel comfortable expressing their ideas and concerns without judgment helps to establish trust among them. Effective team coordination relies heavily on maintaining clear lines of communication (Wenzl et al., 2004). Conflicts are bound to arise in teams that span disciplines due to the perspectives and expertise each member brings (Stokols et al., 2008). By implementing conflict resolution techniques—like engaging in discussions and mediated negotiations—we can effectively

address conflicts in a manner that is friendly to every party. It is worth noting that when handled properly, conflict can actually spur innovation and foster learning among team members. To nurture a research project, it is crucial for all team members to share a vision and have aligned goals (Stokols et al., 2008). When interests and motivations are harmonized towards the research objectives, it enhances commitment and cooperation within the team. The establishment and coordination of research teams play a pivotal role addressing complex sustainability challenges across different fields.

Conflict resolution techniques

Conflicts are bound to occur in research teams due to the range of perspectives, knowledge, and expertise brought together to tackle complex sustainability challenges. Techniques for resolving conflicts within research teams are therefore necessary. Such techniques include establishing open communication, practicing active listening, and creating an environment that encourages communication (Bett et al., 2009). Team members should feel empowered to express their viewpoints, concerns, and suggestions. Active listening plays a role in conflict resolution as it enables team members to understand each other's perspectives and motivations. When conflicts arise, employing mediation can be a technique to facilitate dialogue between conflicting parties. By involving a party, common ground can be identified and negotiations can be facilitated. Through negotiated discussions, team members can collaborate on finding solutions that address conflicting interests (Bett et al., 2009). Reflexive meetings offer a space for team members to introspect on their emotions, assumptions, and reactions during conflicts (Stokols et al., 2008). By promoting self-awareness and acknowledging biases, team members can approach conflicts, with empathy and an open mindset. It is also crucial to establish ground rules and guidelines for resolving conflicts during the team formation process (USGS, 2007). These rules should outline how disagreements will be addressed, the role of team leaders in conflict resolution, and the importance of maintaining communication. By doing so, a positive team culture can be nurtured while preventing conflicts from escalating. Resolving conflicts in research often requires collaboration and compromise among team members. Encouraging a collective problem-solving approach fosters cooperation within the team and facilitates the identification of win-win solutions that consider multiple perspectives (Bett et al., 2009). Because conflict resolution techniques can be time consuming, it is vital to allocate time and create an environment where team members can reflect on the issues at hand (Stokols et al., 2008). Rushed conflict resolution may result in negative outcomes or unresolved tensions. This means that the learning process inherent in a transdisciplinary project needs to be carefully designed and followed.

Transdisciplinary sustainability research is a research practice in itself and, as such, needs to adhere to quality standards, particularly when it comes to adopting and applying research methods (Wiek et al., 2012). However, quality standards in TDR are not as clear-cut as they might be in other academic fields. Apart from scientific credibility, the criteria of saliency and legitimacy demand equal attention in transdisciplinary sustainability research, even though scientists in the present academic system are still primarily judged by the former. This might lead to conflicts between scientists and practice partners, who might have different expectations and enforce different quality standards, particularly when using methods for which both practical and scientific approaches exist.

In a transdisciplinary project in Sri Lanka, this challenge became so serious that the success of the overall project became jeopardized. The project objective was to develop a culturally sensitive, practically applicable, and, nevertheless, scientifically sound planning framework for sustainability-oriented long-term recovery after the 2004 tsunami in the Indian Ocean (Wiek et al., 2010). While researchers insisted on employing and integrating advanced scenario construction and multi-criteria assessment methods into the framework, partners from local NGOs and international aid organizations opted for rather pragmatic tools. The conflicts were never fully resolved but mitigated through increased internal facilitation and mediation. Systematic and criteria-based comparisons between the different methodological options seem to be a promising way to go (Savan & Sider, 2003); yet, in this particular case, it was difficult to realize because of time constraints. The methodology of formative scenario analysis provided a helpful means to cope with these integration challenges (Scholz & Tietje, 2002; Spoerri et al., 2009; Wiek et al., 2006). Using such integrative methodologies can serve as a means to tackle various types of integration challenges (Bergmann et al., 2012).

Finding 4: TDR approach for market intelligence research

Benefits of applying TDR approach to market intelligence research

Market intelligence research plays a crucial role in helping organizations gain a competitive advantage by providing valuable insights into market trends, customer preferences, and competitor analysis. Enhancing the effectiveness and relevance of market intelligence research applying a TDR approach can prove beneficial. One of the benefits of applying the TDR approach is that it encourages collaboration and knowledge exchange across different disciplines. By involving experts from various fields such as marketing, sociology, economics, psychology, and data science, market intelligence research can encompass diverse perspectives and generate insights that go beyond traditional approaches (Smith & Johnson, 2022). This holistic understanding allows organizations to identify underlying market dynamics, emerging trends, and customer behavior patterns that otherwise may be overlooked.

Another benefit is enhanced data integration and analysis. Market intelligence research often involves analyzing large volumes of data from multiple sources. The TDR approach facilitates effective data integration and analysis by bringing together experts with diverse skill sets (Baker et al., 2021). Through collaborative efforts, researchers can combine their expertise in data analytics, statistical modeling, and domain specific knowledge to develop sophisticated analytical frameworks. The integration of market intelligence findings enhances the accuracy and reliability of data, allowing organizations to make confident data driven decisions. Furthermore, it leads to improved stakeholder engagement. One fundamental principle in the TDR approach is active involvement of stakeholders. In the context of market intelligence research, this goes beyond internal stakeholders and also includes external entities such as customers, suppliers, industry associations, and policymakers (Anderson & Carsten, 2020). By engaging these stakeholders throughout the research process, organizations gain valuable insights into their needs, expectations, and perspectives. This collaborative environment ensures that market intelligence research is tailored to address the specific requirements of different stakeholders. Moreover, the TDR approach encourages researchers to consider broader factors that influence market dynamics. This means going beyond traditional market analysis and incorporating perspectives from fields like sustainability, innovation, and social sciences (Peters et al., 2019). By doing so, market intelligence research can identify emerging opportunities and risks that have the potential to disrupt the market. This forward-looking approach enables organizations to proactively respond to changes in the market landscape and adapt their strategies while capitalizing on emerging trends.

Incorporating a TDR approach in market intelligence research presents numerous advantages. It facilitates collaboration among experts from various disciplines, enabling organizations to obtain a comprehensive understanding of the market. Additionally, it enhances data integration and analysis, thus improving stakeholder engagement. Moreover, this approach helps identify emerging opportunities and risks, allowing organizations to make more informed and strategic decisions. Consequently, they can achieve a competitive advantage in dynamic and rapidly evolving markets. Embracing the TDR approach in the field of market intelligence fosters innovation and unveils new insights that contribute to the advancement of research practices.

Recommendations for incorporating TDR principles into market intelligence research

TDR principles offer valuable insights and methodologies that can enhance market intelligence research. By incorporating TDR principles, organizations can expand the scope and depth of their market intelligence efforts, leading to more comprehensive and actionable insights. To achieve this, it is important to establish multidisciplinary teams for market intelligence research. These teams should consist of experts from various disciplines, including marketing, data science, psychology, economics, and sociology. This approach allows for a more comprehensive analysis of market trends, consumer behavior, and competitor analysis (Smith & Johnson, 2022). Collaborative team efforts can facilitate the integration of diverse perspectives and generate holistic insights.

Another important factor in conducting market intelligence research is stakeholder engagement. It is crucial to involve relevant stakeholders throughout the research process. This includes internal stakeholders such as marketing teams and decision makers as well as external stakeholders such as customers, suppliers, and industry experts. Actively involving stakeholders ensures that their perspectives and insights are integrated into the research findings (Anderson & Carsten, 2020). This engagement can be achieved through various methods like interviews, surveys, focus groups, and workshops to gather diverse viewpoints and enhance the relevance of market intelligence outcomes.

To conduct effective TDR research in the realm of market intelligence, it is crucial to incorporate systems thinking. This principle emphasizes recognizing the interconnected nature of different factors that influence the marketplace. An understanding of the wider socio-economic contexts as well as technological advancements and environmental aspects within which businesses function is essential (Peters et al., 2019). Adopting a systems thinking approach allows organizations to identify complex relationships between various elements such as market dynamics and external influences alongside internal business strategies.

Market intelligence endeavors often rely heavily on quantitative data analysis techniques like surveys and market data. However, incorporating qualitative methods including interviews, ethnographic research, and observational studies can enrich the insights obtained and the contextual understanding of customer needs and preferences (Baker et al., 2021). By integrating these qualitative methods with quantitative approaches, organizations gain a more comprehensive understanding of market dynamics as well as customer behavior. Consequently, organizations can develop highly targeted marketing strategies that align with their findings. The TDR principles underscore the importance of continuous learning and adaptation in conducting successful market intelligence research processes. It is crucial to have an iterative approach that involves collecting new data continuously, actively analyzing it and refining strategies based on emerging insights (Smith & Johnson, 2022). By embracing this ongoing process-driven mindset, organizations remain responsive to changing conditions within the marketplace. In doing so, they are able to adjust their strategies effectively.

To foster successful research outcomes in this context, organizations should cultivate a culture that values learning and adaptability. This includes encouraging teams to continuously refine their research approaches and strategies based on ever-changing market dynamics.

Finding 5: TDR approach as a transformative research practice in crop breeding

Benefits of using a TDR approach

Crop breeding plays a role in ensuring food security and sustainable agricultural practices. This is particularly crucial given the challenges posed by climate change and the growing global population. The transdisciplinary approach has emerged as a research practice in crop breeding by bridging the gap between knowledge and indigenous wisdom. This review has identified several ways in which TDR approach is of importance to crop breeding.

First, the collaboration, between stakeholders, including scientists, farmers, policymakers, and local communities, is crucial in crop breeding. This transdisciplinary approach combines knowledge with wisdom to gain a comprehensive understanding of the challenges and opportunities in crop breeding. By incorporating varied perspectives, this collaborative effort leads to the discovery of context-specific solutions.

Advancements in the approach to crop breeding have been made through methodologies and practices. Participatory research and farmer engagement are now elements of this approach (Kates et al., 2001). Involving farmers in the breeding process ensures that the goals align with their needs and preferences, resulting in relevant crop varieties. Furthermore, technological advancements like high throughput genotyping and phenotyping have facilitated the integration of data, into breeding (Wenzl et al., 2004). This integration enhances precision and efficiency in selecting traits that contribute to sustainability and resilience.

The TDR approach of combining disciplines in crop breeding offers exciting opportunities for further progress. Firstly, by harnessing the power of data analytics and machine learning, we can make sense of amounts of information from various sources like climate models, genetic databases, and socio-economic data. This data-driven approach provides insights into how genetics the environment and social factors interact with each other, leading to informed decisions when it comes to breeding crops.

Secondly, collaboration between the private sectors can greatly benefit the approach. By partnering with seed companies and agricultural technology firms, we can speed up the distribution of improved crop varieties and technologies to farmers. This collaboration will encourage adoption of these advancements in farming practices. However, despite its advantages, there are also challenges associated with the approach in crop breeding. One major challenge is the lack of coherence when it comes to defining problems due to differing perspectives from stakeholders (Brandt et al., 2013). Overcoming this hurdle requires communication and a deep understanding of each stakeholder's goals and priorities. Another challenge lies in integrating methods since crop breeding involves multiple scientific fields such as genetics, agronomy, and climatology (Schäfer et al., 2021). Finding ways to harmonize these methods

and ensure collaboration among researchers with expertise is no small task.

Potential challenges

TDR approaches have become increasingly important in the field of crop breeding as they integrate Indigenous knowledge to tackle agricultural challenges. These innovative approaches offer advantages, such as enhancing livestock genetics and promoting smallholder systems (Ahuya et al., 2005; Haile et al., 2019). However, similar to any other approach, TDR in crop breeding faces potential obstacles that must be recognized and addressed in order to fully unlock its potential. These challenges encompass issues related to framing the research question, integrating methods, managing the research process, engaging with practitioners effectively, and scaling up successfully. One crucial challenge in transdisciplinary crop breeding research involves establishing a shared understanding of the problems among stakeholders having different backgrounds (Gibbons, 1999). Researchers and practitioners may hold different perspectives on the research question at hand. This divergence can make it challenging to align their approaches effectively. Without a framework in place, misunderstandings can hinder the collaborative efforts necessary for successful transdisciplinary projects. TDR involves combining methods from different fields to address the challenges of crop breeding (Bergmann et al., 2012). However, merging these approaches can be time consuming and complex. Researchers need to navigate through ways of collecting, analyzing, and interpreting data to create a research framework that utilizes the strengths of different disciplines. In transdisciplinary crop breeding research, it's not about describing systems but also analyzing problems, coming up with solutions, and applying them in real-world situations (Lang et al., 2012). This comprehensive research process requires collaboration and interaction between scientists and practitioners. Striking a balance between the expectations of stakeholders and ensuring knowledge generation is a challenge that researchers must handle. The level of involvement with practitioners plays a role in the success of research (Krütli et al., 2010), and it is important to engage practitioners at a level that ensures the research remains relevant and applicable. However, determining the degree of practitioner involvement can be difficult. Insufficient engagement may lead to limited research outcomes, while excessive involvement may consume excessive time and resources. While TDR approaches hold promise, it is common for initiatives to primarily concentrate on localized areas (Kengeya-Kayondo, 1994). However, extending the scope and applying research findings to diverse regions and agricultural systems can be quite challenging due to the context in which these outcomes are achieved. Hence researchers must exercise caution when attempting to scale up their findings without sacrificing the practicality and significance of their results

Addressing tradeoffs in TDR on breeding and how to overcome these challenges

TDR shows promise in tackling challenges in breeding. However, implementing TDR requires management of tradeoffs. It is therefore necessary to highlight the literature on these tradeoffs and suggest strategies to mitigate them. By acknowledging and addressing these tradeoffs, researchers and practitioners can maximize the potential of TDR in crop breeding.

It is evident from similar research that TDR requires significant time and resources due to its collaborative and interdisciplinary nature (Sievers-Glotzbach et al., 2020). Researchers and stakeholders need to balance the time and resources invested in TDR activities while ensuring the achievement of desired breeding outcomes. Finding the balance between time allocation and resource management is essential for attaining breeding objectives. Addressing such a tradeoff is a prerequisite to success in breeding research. Moreover, literature shows that striking a ground between understanding and taking actionable steps can be challenging due to the complexity that TDR often entails (Messina et al., 2020). Different disciplines within TDR may have varying terminologies, methods, and perspectives. Bridging the communication gap and fostering comprehension among disciplines are also identified as vital aspects.

Additionally, TDR aims to integrate diverse knowledge systems, including scientific and Indigenous knowledge. However, integrating these different knowledge systems requires careful navigation (Maciver & Malins, 2016). In order to balance the myriad factors, it is crucial to involve all stakeholders—which includes breeders, researchers, policymakers, and end users—throughout the research process. By collaborating with them, we can ensure that the research is relevant and applicable to their needs (Kaumbata et al., 2021). It is important to involve stakeholders in shaping the research questions and objectives so they can identify and prioritize the tradeoffs that are specific to breeding. Open and transparent communication about these tradeoffs is essential for managing expectations and building trust. Additionally, being flexible and adaptable is key as TDR should be able to respond to emerging tradeoffs and adapt to evolving breeding systems. Effectively addressing these tradeoffs is crucial for implementing TDR in breeding. This summary has highlighted the challenges associated with TDR in breeding research and provided recommendations to mitigate them. By considering these strategies, researchers and

practitioners can fully utilize the potential of TDR to promote innovative breeding practice.

Conclusion

In conclusion, TDR is a useful approach to solving problems in modern society. The collaboration among different stakeholders and scientists in knowledge creation for the benefit of society is key to sustainable development. Different disciplines uphold varying methods towards solving sectoral problems; however, TDR ensures a multi sectoral approach by combining different techniques to provide a lasting solution that cuts across multiple perspectives. Although TDR has multiple benefits related to environment conservation and sustainability, it faces a number of challenges inherent to the nature of TDR; mainly, collaboration and interaction among various actors. The history of TDR demonstrates how it has evolved as an approach that goes beyond the boundaries of disciplines to tackle complex real-world problems. Its underlying principles emphasize the integration of knowledge systems promoting learning, between scientists and practitioners. Effective practices in TDR involve collaborating to solve problems, involving stakeholders, and creating knowledge together. The composition of a team plays a role in the success of TDR initiatives because having expertise and methodological skills contributes to comprehensive problem solving in crop breeding. Combining market intelligence with TDR provides insights into consumer preferences, improving crop breeding techniques, and ensuring their relevance in the market. TDR also faces challenges such as the need for framing, integrating methods, engaging practitioners, and scaling up research outcomes. To overcome these challenges, researchers must foster collaboration, establish shared definitions of problems, and develop new methods. Engaging stakeholders at all levels and carefully considering scaling strategies are essential for realizing the potential of TDR in crop breeding. By embracing these solutions, we can ensure that TDR continues its journey by fostering impactful solutions for agricultural challenges.

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Appendix 1: Search Terms

		Search Terms
		Transdisciplinary OR Trans disciplinarity OR "Transdisciplinary research" OR "interdisciplinary research" OR "co-creation of knowledge" OR "trans-disciplinary teams" OR "stakeholder collaboration" OR "Collaborative research" OR "knowledge co-production" OR "communities of practice" OR "research networks"
Finding 1	AND	Epistemology OR ontology OR theory OR History
Finding 2	AND	"Research design" OR "Project scope" OR "data collection and analysis" OR "stakeholder engagement" OR "best practices" OR "Industry standards" OR "Successful methodologies" OR "effective approaches"
Finding 3	AND	"Team composition" OR "team building" OR "Conflict resolution" OR "team management" OR expert OR "domain experts' OR "methodological experts" OR "team dynamics"
Finding 4	AND	"Market intelligence research" OR "market intelligence" OR benefits OR "Advantages" OR "market research" OR "marketing research"
Finding 5	AND	Breeding OR crop breeding OR plant breeding OR "seed breeding" OR "Benefits" OR Challenges OR setbacks OR drawbacks

Web of Science; Scopus;

Google Scholar; Gray Literature


ICARDA
Science for resilient livelihoods in dry areas


CGIAR
GENDER
Platform


CGIAR
INITIATIVE ON
Market Intelligence