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The Adoption and Implementation of Transdisciplinary Research in the Field of Land-Use Science—A Comparative Case Study

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Abstract: Transdisciplinary research (TDR) is discussed as a promising approach in land-use science and spatial research to address complex multifaceted "real-world problems" and to design strategies and solutions for sustainable development. TDR has become a widespread research approach in sustainability science and is increasingly promoted by research programmes and agencies (e.g., Future Earth and Horizon 2020). Against this backdrop, TDR can be considered a (social) innovation in the academic system, which is currently in the midst of an up-scaling diffusion process from a rather small TDR-advocating expert community to a broader science-practice community. We argue that this up-scaling phase also places TDR in a critical state as the concept potentially risks a type of "rhetorical mainstreaming". The objectives of this study were to analyse how the challenging approach of TDR is currently adopted and implemented in the field of land-use research and to identify potential influencing factors. We studied 13 transdisciplinary research projects from Germany by performing qualitative interviews with coordinators, document analysis and participatory observation during meetings over a period of five years. Results show that the adoption level of the TDR concept varied widely among the studied projects, as did the adoption of the TDR indicators used in our analysis. In many of the investigated projects, we identified a clear lack of conceptual knowledge of TDR. In addition, we found that current academic structures limit the ability of researchers to thoroughly adapt to the requirements of TDR. We conclude that further communication and educational efforts that promote TDR are required. In addition, we advocate for the development of suitable funding instruments that support sustained research structures.

Keywords: transformation; social innovation; science-practice collaboration; participatory research; research policy

1. Introduction

Land-use practices and spatial development cover a wide range of sustainability problems. Increasing change in land use often causes environmental damages that reach far beyond the local scope [1]. Different interests and demands as well as values and norms compete for limited land resources and the related ecosystem's services and functions (e.g., Müller et al. [2], Zscheischler et al. [3]). Spatial development faces high degrees of complexity and uncertainty as it "operates in a world of becoming" under ever-changing societal, economic and biogeophysical conditions [4].

These challenges have been amplified by global changes that include land-related issues such as climate change, urbanisation, and decreasing biodiversity [5]. Thus, the demand for societal transformation towards sustainability has been increasingly discussed over the last two decades and

has evolved into a major issue in politics, science and planning. Transformation is considered to involve comprehensive changes in behaviour and practices by a multitude of actors and institutions [6], which requires knowledge to not only understand the interplay of current drivers and inhibitors of global change but also to develop strategies and solutions that lead to desired future development [7,8].

In this regard, collaborative research approaches such as inter- and transdisciplinarity are considered promising means of initiating change in the current course of action. Numerous authors have defined transdisciplinary research (TDR) as a collaborative process of knowledge production that involves scientists from different disciplines and societal actors and is aimed at addressing highly complex, real-world problems (e.g., Pohl [9], Wickson et al. [10], Wiek [11], Roux et al. [12], Toetzer et al. [13]). TDR can be understood as a research-guiding principle and a form of organisation [14] that integrates different knowledge types and incorporates processes of co-design and co-production [15]. As described here, TDR shows many commonalities with action-research approaches, such as community-based action research (CBPAR) (e.g., Horowitz et al. [16], Minkler [17]) and transdisciplinary action research (TDAR) (Stokols [18], Thering and Chanse [19]), which are preferred in the American context.

Many scholars have emphasised the potential contributions of TDR, such as its ability to increase stakeholder decision-making capacity by providing "socially robust" and implementable knowledge [20,21] and rationalising conflicts [22,23], to accommodate complexity [9] and to integrate various perspectives and sources of knowledge [10,24,25]. Presently, TDR has become increasingly widespread [26–28], promoted and institutionalised (e.g., Future Earth, Horizon 2020). It has progressively become mandatory for funding, requiring a change of research practice.

Against this backdrop, we consider TDR a social innovation in the academic system (see also Blättel-Mink and Kastenholz [29], Novy et al. [30]). There are numerous interpretative patterns of the term "social innovation" and corresponding heterogeneous theoretical approaches. In accordance with others (e.g., Taylor [31], Brooks [32], Schubert [33]), we conceive of social innovation as an extension of the notion of technological innovation. Thus, we do not consider social innovations as distinctive or opposite to techno-economic innovations but as a broader interpretation. We define "social innovation" as "new" practices that provide alternative solutions to persisting problems [34] driven by specific actors in specific operating contexts [35,36]. We argue that, currently, TDR is in the midst of an up-scaling diffusion process from a rather small TDR-advocating expert community to a broader science-practice community or from a systems theory perspective in a phase of restabilisation (cf. Besio and Schmidt [37]). In this stage, it is determined whether an innovation will result in structural changes, remain in the phase of variation, or whether the innovation process will be terminated (see also Luhmann [38]).

Hence, this stage places TDR in a "critical state". Pohl [39] found that, to many researchers, TDR is just another demand among others in research programmes. Consequently, researchers might be tempted to comply in name ("rhetorical mainstreaming"; Jahn and Keil [40]) but not in fact to secure their share of available funds [41]. In science, this form of "window dressing" often plays an important role in securing funding [42].

Previous empirical studies have addressed the challenges, obstacles, and facilitators in implementing TDR (e.g., Blättel-Mink and Kastenholz [29], Tress et al. [43], Jakobsen et al. [44], White et al. [45]). However, information on the quality of transdisciplinary processes remains scarce [46]. To date, the framing of TDR as a form of (social) innovation in a diffusion process has been uncommon; however, framing TDR in this way might provide knowledge on influential factors for the adoption and implementation of the TDR approach. In addition, individual case studies are the most common contributions to TDR and almost exclusively reflect the scientific perspective on a collaborative process (Zscheischler and Rogga [47]). In contrast, few comparative studies have been conducted (e.g., Zierhofer and Burger [48], Enengel et al. [49], Campbell et al. [7]).

The aim of this paper is to examine how the challenging approach of TDR is adopted and implemented in the field of land-use research performed under similar conditions (same funding

programme). The comparative analysis is aimed at identifying potential explanatory factors and assessing their relevance for the adoption of the TDR approach to discuss implications and conclusions for better disseminating this approach.

2. Research Design

2.1. Case Selection and Access

To analyse the adoption and implementation of the TDR concept, we studied 13 transdisciplinary joint research projects. These projects were funded by the same German funding programme, which was aimed at the development of sustainability solutions for land use-related challenges in Germany. Project objectives included the development of innovative value creation networks for sustainable regional development, new instruments and concepts of resource efficiency for settlement development, decentralised systems of renewable energies, and new technologies supporting sustainable land-use systems [50]. Project duration was between three and five years.

Application of the TDR approach was a pre-requisite for funding, with the call for proposals explicitly referencing a TD concept to integrate knowledge from different disciplines (especially the integration of knowledge from "natural scientific-technological and economic-social scientific disciplines") and involving practitioners such as "decision-makers" and "key actors".

The authors were members of an associated scientific coordination project (SCP) that accompanied these 13 joint research projects over a period of five years (2010–2015). The SCP encouraged interaction and mutual learning among the members of all 13 research projects and supported the identification and examination of cross-cutting themes. As one topic of focus was TD, the SCP initiated discussions and workshops addressing this issue. The SCP had no direct influence on the adoption of the TDR approach but presented the researchers with possibilities for reflecting TDR processes in their projects. Concurrently, the SCP also initiated and observed communication processes among project members regarding TDR. Hence, the conditions provided particularly valuable access to the field; numerous informal discussions were complemented by insights from documents and multiple meetings. Hence, the case selection was strongly driven by the access provided via the SCP.

2.2. Research Design

The research design is based on an iterative research strategy using an inductive-deductive approach. We began with an explorative phase to develop the research field. We then developed an analytical framework derived from a literature review of the key principles of TDR and the factors that are important for the adoption of social innovation. This framework guided our data collection and analysis. During the analysis process, additional inductive categories were derived from the material.

2.3. Data and Material

The results of this study are based on the analysis of empirical data from different sources, obtained via the following procedures:

(1). We continuously conducted participant observation during conferences and project workshops, resulting in field notes and protocols (see Figure 1) focussed on communications (informal talks, discussions, and presentations) regarding the TDR approach and corresponding experiences, notions, attitudes and settings. In accordance with de Walt and de Walt [51], we used the observation method to develop a comprehensive understanding of the adoption process of the TDR approach. This method was beneficial for applying and adjusting our analytical framework, developing an interview guide and validating the findings from document analysis and interviews.

(2). We performed document analyses of project proposals, reports and web pages from all 13 research projects to explore the planning, operationalisation and implementation of transdisciplinary processes. We applied the categories of our analytical framework and complemented them with inductively derived categories related to the TDR concept.

(3). We conducted and transcribed semi-structured interviews with coordinating researchers to gather information regarding the initial phase of the projects, interdisciplinary collaboration and knowledge integration, and the implementation of practitioner involvement. Although additional interviews with other project participants would have been valuable, we focussed our study (due to resource limitations) on coordinating researchers as the most valuable knowledge carriers and key actors in enabling and constraining the implementation and adoption of the TDR process. In total, we conducted 14 interviews between September and November 2015. For the comparative case analysis, we selected 10 projects based on the sufficient depth and specifications of the interviews. Results of the interviews (presented in "The adoption of the TDR approach in 10 transdisciplinary joint research projects") are supported by direct quotes (Q n) listed in Supplementary Data.

In summary, the analysis combines material from different project phases (ex ante: project proposals; in operando: protocols of meetings and field notes from participant observations; ex post: interviews following project completion).
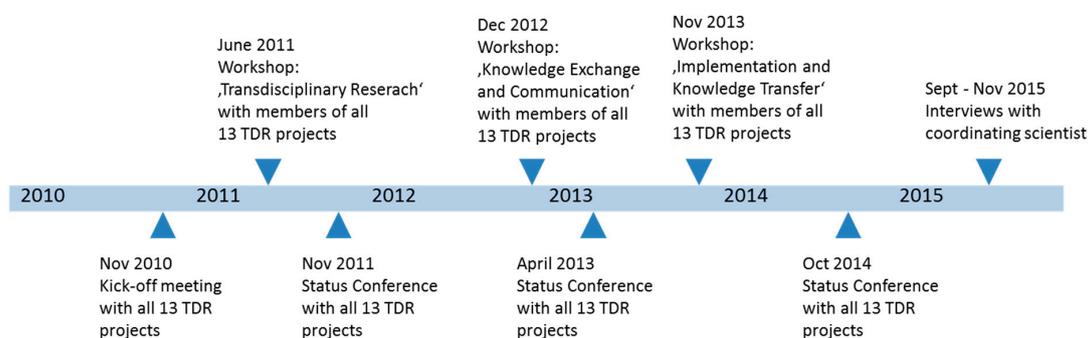
Figure 1. Timeline of the events of data collection.

2.4. Qualitative Content Analysis

The interviews, documents and field notes were evaluated and interpreted following the guide of qualitative content analysis according to Mayring [52]. Data processing was performed using the software MaxQDA. After developing an initial analytical framework based on a literature review of the key principles of TDR and the main factors influencing the diffusion processes of social innovations, we developed and refined a category system for the complete material using coding (preferentially using in vivo codes) and paraphrasing (proposition-wise from the interviews; selective from the documents and field notes). Further themes were derived through an iterative process of rereading, following the recommendations of Ryan and Bernhard [53] (cit. after Bryman [54]). Iteratively, we generalised and reduced the analysis corpus by means of the summary technique. In a further step, we explicated and contextualised distinctive (incomplete or contradicting) propositions by linking the different types of material and codes. Subsequently, individual cases were summarised and described according to the final category system. In a final step, results were critically discussed and validated within the team of the SCP.

3. Analysing the Adoption of TDR: A Set of Key Features and Factors

To study the adoption of the TDR approach, we reviewed the current literature to extract key features of TDR and corresponding indicators to assess TDR adoption in the projects and to identify influencing factors for the adoption of social innovations.

3.1. Indicators for the Adoption of the TDR Approach

Many scholars have discussed what defines a "good" TDR practice. For the analysis, we focussed on the features described below (Sections 3.1.1–3.1.3) as they are the features most feasibly studied

from an external perspective and are regarded the most appropriate for reflecting the adoption of the TDR approach.

3.1.1. Collaborative Problem Framing and Co-Designing the Research Process

TDR is oriented towards the solution of complex real-world problems (e.g., Hirsch Hadorn et al. [55], Roux et al. [56], Mobjörk [24]). Accordingly, many scholars emphasised the need to integrate knowledge, perspectives and interests not only from different disciplines but also from related societal actors when the research project is designed (e.g., Bergmann [57], Tress et al. [58], Wiek [7], Enengel et al. [49], Goebel et al. [59], Lang et al. [28]). The initial phase is considered especially critical, as, in this stage, the most important goals, financial and staff margins, procedural operation possibilities, and limits of the management capacities of the project are determined. Following Lang et al. [28], this phase "orients, frames and enables the core research process." Hence, it should include: (1) the joint identification and definition of the complex real-world problem; (2) the joint formulation of research objectives and the research question; (3) a conceptual and methodological framework for knowledge integration; and (4) the formation of a collaborative research team. We used these determinants as deductive categories for our analyses.

3.1.2. Integrating Knowledge from Different Disciplines (Interdisciplinarity)

Another key feature of TDR is "interdisciplinarity". Originally, the term "transdisciplinarity" was introduced to further clarify the concept of "interdisciplinarity". The resulting notion of TDR as a "perfected interdisciplinarity" persists today, as particularly evidenced by regional differences between Europe and the US [47,60]. In the North American debate, the notion of TDR originated from the "taxonomy of cross disciplinary research" after Rosenfield [61] used the lexical morpheme "trans" to describe a collaborative research approach differing from interdisciplinarity in which researchers "work jointly but still from a disciplinary-specific basis" transcending disciplinary boundaries by "using shared conceptual framework drawing together disciplinary-specific theories, concepts, and approaches to address common problems". Interdisciplinarity is different from multidisciplinarity. The latter refers to the collaboration of disciplines that "relate to a shared goal, but with multiple disciplinary objectives" [58]. In contrast, to our understanding, interdisciplinarity is described by the following principles, which we used for indication: (1) the involvement of several unrelated academic disciplines (with contrasting research paradigms) in a way that forces them to cross subject boundaries [58]; (2) while targeting a common goal [62,63]; (3) leading to interdisciplinary theory development; and (4) the merging of concepts and methods [64].

3.1.3. Science-Practice Collaboration

A third key feature of TD is that of transcending academia and involving societal actors "on equal footing" (e.g., Aeberhard and Rist [65], Baumgärtner et al. [66], Klein [67], Vandermeulen and Van Huylenbroeck [68], Scholz and Steiner [64]). However, science-practice collaboration is not limited to TDR. Other approaches, such as participatory action research [69], citizen science [70], and consultancy [15,48] are also characterised by science-practice collaboration.

The differences between TDR and other approaches can be found in the function of involvement and the roles of scientific and societal actors [24,71,72]. Furthermore, Scholz [15] distinguishes between transdisciplinary processes and TDR: whereas the former is a joint-controlled process, the latter is led and controlled by researchers. Hence, the decisions of who should be involved and how and when they should be involved depend strongly on the coordinating researchers of TDR projects. Different forms of involvement are discussed in the literature. Mobjörk [24] differentiates between "consulting transdisciplinarity" (meaning involvement that is limited to responding) and "participatory transdisciplinarity" (referring to fully and equally incorporating knowledge from societal actors with scientific knowledge). Pohl [39] describes the specific quality of transdisciplinary collaboration as "interrelating" perspectives and knowledge instead of simply "adding". Furthermore, Stauffacher [71]

and Wiek [11] distinguish different levels of involvement: one-way information, mutual one-way information (mutual learning), collaborative research, and joint decision-making.

To summarise, there are several perspectives and no "one-size-fits-all solution" [71,72] regarding the framing and organisation of science-practice collaboration in TDR. Nonetheless, we identified some common principles that we consider to be mandatory regarding science-practice collaboration in TDR projects: (1) TDR organises and enables mutual learning processes between science and practice and hence must not be limited to data collection and information from societal actors. (2) Knowledge and perspectives must be integrated and interrelated in a cooperative manner. (3) Science and practice must collaborate "on equal footing" [64]. (4) TDR integrates "two pathways": one pathway that is focussed on solving societal problems and one that contributes to scientific knowledge gain by developing "interdisciplinary approaches, methods and general insights" [11,28].

3.2. Factors Influencing the Adoption Process

To better understand the adoption and application of the TDR approach, we additionally studied potentially explanatory factors (Sections 3.2.1–3.2.3), which are widely discussed in the field of (social) innovation research:

3.2.1. Knowledge of an Innovation: Notions of the TDR Concept

The diffusion theory by Rogers [35] distinguishes different phases that compose the decision process for adopting an innovation. In the first phase, knowledge plays a crucial role. In this phase, the potential adopter gains three types of knowledge regarding an innovation: (1) awareness-knowledge (knowledge of the innovation existence); (2) how-to-knowledge (knowledge on how to use the innovation); and (3) principles-knowledge (how and why an innovation works).

Knowledge is considered a decisive factor in the innovation-decision process. The likelihood of adoption increases with the level of "how-to-knowledge" and is especially critical with more complex innovations. Sahin [73] emphasises the importance of "principles-knowledge", stating that "innovations can be adopted without this knowledge, but the misuse of the innovation may cause its discontinuance". Adequate communication can be regarded as critical for the up-scaling process [74]. As an indicator of the factor of "knowledge", we studied the understanding of the TDR concept by scientists in the considered research projects.

3.2.2. Attitudes and Willingness to Adopt the TDR Approach

In the phase of up-scaling and diffusion of an innovation, communication becomes essential not only for enhancing knowledge regarding an innovation but also for shaping the attitudes of adopters, which in turn decisively influence the adoption or rejection of an innovation. The attitude (negative or positive) towards an innovation is strongly influenced by social reinforcement, for example, via colleagues or the community [35] and through social norms and values [74]. Mulgan [75] emphasises the importance and necessity of supporters such as funders. In addition, the success of a social innovation depends on the persuasive skills of innovators. Here, the credibility of the advocators plays a central role [76]. With respect to the factor of attitude and willingness, we studied the attitudes of scientists towards the TDR approach and their motivation to participate in a TDR project.

3.2.3. Compatibility of an Innovation with the Social System

A decisive factor for adoption is the compatibility of the innovation with the social system and social structures. Cajaiba-Santana [77] stresses the need to consider social structures as they enable and constrain agents while acting upon those practices (see also Esser [78]). These structures, which refer to the institutional setting (norms, conventions, and values), can be regarded as composing a "framework that guides individual and collective action" [79]. Giddons [80] regards structures as "both medium and outcome of the reproduction of practices" (p. 5).

In this respect, we define academic structures as collective patterns that determine the opportunities and restrictions of scientific practices, including funding conditions, disciplinary cultures, career pathways, scientific credibility, and powers and duties. To analyse the compatibility of TDR with academic structures, we investigated the call for applications and considered critical reflections on the framing conditions documented in the interviews, workshop protocols and field notes.

4. Results: The Adoption of the TDR Approach in Investigated TDR Projects

This section presents the results of a comparative case analysis of TDR adoption. The entire investigation comprised 13 joint projects. However, for the analyses (especially those referred to in Sections 4.1 and 4.2.3), 10 cases were used for comparison due to a lack of interview data in the remaining three cases, which provided sufficient depth only.

Table 1 provides an overview of the main categories and corresponding characteristics of the investigated ten TDR projects. Deductive categories reflecting the presented analytical framework (see above) were complemented by inductive categories derived from the material.

Table 1. Results of qualitative content analysis (sources: interviews and field notes).

Type of Reasoning	Indicator	Case Number									
		1	2	3	4	5	6	7	8	9	10
Key Features of TDR											
Collaborative Project Development											
deduction	Joint problem identification	+	−	(+)	(−)	−	(+)	(+)	(−)	−	−
	Joint formulation of objectives and research question	(+)	−	−	−	−	(+)	(+)	(−)	−	−
	Concepts and methods for knowledge integration	(+)	−	−	−	−	(+)	+	−	−	−
induction	Primarily based on pre-existing networks	+	+	+	+		+	+	+	+	+
	Disciplinary background of coordinators	S	a N	Eng	a N	a N	Plan	S/N	a N	Plan	Plan
Interdisciplinarity											
deduction	Involvement of unrelated disciplines	+	+	(+)	+	+	+	+	+	+	+
	Addition of knowledge	+	+	+	(+)		-		+	+	+
	Targeting of a common goal	+	+	+	(+)	+	+	+	(+)	(+)	+
	Interdisciplinary theory development	−	−	−	−	−	−	−	−	−	−
	Merging concepts and methods	−	−	(+)	−	+	+	−	−	−	(+)
	Mutual learning	+		(+)		+	+	+	+	−	
induction	Hidden research agenda/Ignorance	−				+			+	+	
	Natural scientists dominate	−	+	−	+	+	+		+		
	Social scientists have a service role	−	+	−	+	+		(+)	+	−	
	Social scientists involved to obtain funding	−	+		+		−	−	+	+	
Practice and Science Collaboration											
deduction	Organises and enables mutual learning	+	(+)		+	−	+	+	(+)	−	(+)
	Knowledge Integration	+	+	+	+	−	+	+	−	−	−
	Equal footing	+				−	+	+	−	−	−
	Balanced benefits	P	P	P	(+)/P	Sc	+	(+)	Sc		Sc

Table 1. *Cont.*

Type of Reasoning	Indicator	Case Number									
		1	2	3	4	5	6	7	8	9	10
Key factors for the adoption of social innovations											
Knowledge of TDR Concept											
Induction	TDR is a vague/"just a new concept"	(+)	+		+		+	(+)			+
	TDR is science and practice together	+	+		+	+	+	+	+	+	+
	TDR is interdisciplinarity			+		+	+	+	+	+	
	TDR is applied research			+	+				+		+
	Previous TDR experience	+	(+)	(−)	−	−	(+)	(+)		(−)	(−)
	Knowledge integration										
	Mutual learning										
Attitude towards the TDR Approach/Motivation											
deduction	Positive general attitude	+	+	+	+	+	+	−/+	(+)	−	+
induction	Desire to contribute to a transformation in land use	(+)	+	(+)	+						
	Strong pressure for third party funding/employment		+	+	+			(+)		+	
Compatibility with Academic Structures											
induction	Not compatible with academic structures/scientific culture	+	+		+	+					+

+ Largely applies; (+) Partially applies; (−) Does rather not apply; − Does not apply; S: Social science; a N: Applied natural science; Eng: Engineering science; Plan: Planning science; P: Primacy of practice; Sc: Primacy of science.

4.1. Variation in Adopting and Implementing a TDR Process

4.1.1. Collaborative Problem Framing and Co-Designing the Research Process

Results show that a broad range of approaches was used to frame the research problem, define the research question and build up the consortium. A small number of projects strived to achieve an iterative process of collaboratively framing the research problem and the resulting research question in which the actors from practice were involved from the beginning and had a voice on equal footing (P1, P6, and P7). However, this process was based on different settings: Project 7 reported that they chose a reduced form of collaborative problem framing during the application phase but compensated for it immediately after the project start, whereas Project 6 was already in an intensive collaborative science-practice process when the call for funding was announced. In contrast, there were several research projects in which only a small group of researchers or an individual researcher was involved in formulating the research problem and research question, designing the entire project, and deciding who should be involved. Partners from practice were involved only to the extent of providing letters of intent to participate. In these research projects, neither criterion was rated as fulfilled (see Table 1).

Nearly all of the projects exhibited identical action patterns following the announcement of the call for proposals, which generally represented the initial moment of project application. Many projects showed a long history of consecutive funding phases, slightly changing and updating their core research questions to meet the requirements of the announcement. The selection of the scientific and practice partners and the project objectives were mainly based on pre-existing contacts and networks. This pattern can be observed in nine projects, thus stressing the importance of mutual trust and network reliance in project partner selection. In an extreme case (P2), the project partner selection process sought to maintain an "old boys" network (patronage):

"... which is also related to the person A. He is very strongly network oriented and works very strongly with his mates together. And if he wants to do something, he always looks first for his trusted people. And if someone is familiar with him, he would not look for a better alternative. He's

going to try to cover a certain topic with his friends before he might choose a more appropriate partner... "

Only one project (P7) had developed an explicit concept for knowledge integration. In two other cases, implicit concepts could be assumed due to the documented project design and reported ideas regarding involvement.

4.1.2. Integrating Knowledge from Different Disciplines

In all of the projects, scientists from a broad range of disciplines were involved. However, involvement had a prevailing character of additive composition (Q18 and Q19). Interdisciplinary collaboration that integrated conceptual frameworks and theory from different disciplines was sporadic and frequently not strategically planned or managed. This sporadic collaboration was also evidenced in project structures in which the sub-projects were separated by discipline. Some coordinators commended this autonomous work style as an asset as it promotes efficiency and minimises the work load (P2 and P4). Other projects had involved disciplines to be "well-rounded" but admitted that these disciplines could be omitted (P4 and P8). These cases represented the largest projects of the funding programme, with approximately 60 scientists involved. Remarkably, projects that managed to merge concepts and methods shared a common overall concept (vision development process), which served as a boundary object and provided guidance for collaboration.

The dominance of natural scientific-technological disciplines was apparent in many cases (Q15, Q16). In two projects, scientists with a social scientific background were responsible for (P1) or were involved in coordination (P7). In many other projects, social scientists were not only outnumbered (the P4 coordinator estimated a relation of 5 to 55) but also regarded as a "service-discipline" to facilitate stakeholder processes, working as transfer agents or science communicators (P2, P4, P5, P7, and P8). This revealed a marginalised importance and low expectations of social scientists' work (Q17). One coordinator observed that social scientists were not considered in the coordination activities:

> " . . . *We also had our colleagues from the socio-economy or the social sciences from socio-geography, which is really quite strange to us, but of course it was difficult for us to co-ordinate, because they had to find out on themselves, to see what they do ...."* (P4)

Few coordinators reported an increase in acceptance between natural and social science perspectives over the course of the project. Many coordinators reported and welcomed the opportunities for mutual learning processes in TDR projects (Q34–Q36).

Another reported phenomenon was the "hidden research agenda", which occurred in two forms. In one form, several scientists had promised results in the application phase, but after the project start, they followed their own research agenda and supplied few results to the joint project (P5, P8, and P9). In the second form, four coordinators openly admitted that social scientists were involved in the project only because of strategic considerations; i.e., maximising grant opportunities (P2, P4, P8, and P9). One interviewee explained this flawed interdisciplinarity:

> *"Well, 'interdisciplinary'—in my experience this is mainly demanded by calls for proposal, and then (scientists) respond to it and this interdisciplinarity—well—I don't want to say it is faked, but it is tried to be constructed."* (P9)

In general, the focus of coordinators was less on interdisciplinary research and more on practice-science collaboration.

4.1.3. Science-Practice Collaboration

The quality and role of practitioner involvement varied widely among the projects. In three projects, the science-practice collaboration had a central role and was designed as a process with equal footing (P1, P3, P6, and P7). In these projects, knowledge, interests, and perspectives from practice

were considered in much of the researchers' work. Regular meetings between science and practice led to mutual learning.

In other cases, the involvement of practitioners was selective and focussed on product development or on process engineering, and it was accompanied by public relations work or consultancy workshops, indicating a rather traditional understanding of one-way information transfer (P2, P4, and P8). In one case (P5), one of the largest consortiums (approximately 35 partners) underwent an intense stakeholder dialogue process that involved more than 60 actors from practice. However, these activities remained completely independent from the core item of the project, which led to frustration for both the dialogue moderators (social scientists) and societal actors. In all of the studied projects, non-academic actors were classified as "partners" (bound to the project through contracts) or as "actors" (involved through interviews and surveys, focus groups or workshops). Practice partners (municipalities, public authorities, NGOs, consultancies and small and medium-sized enterprises) were often bound to the project via (co-funded) employment at their respective institution. In some cases, specific work packages were outsourced to providers that had been termed "non-scientific project partners". Another frequent notion of involvement was regarding landowners as project partners who provided testing areas (P2, P3, P4, and P8).

In many projects, information transfer and consultation events clearly outweighed more integrative approaches and methods. Stakeholder and public acceptance of science activities and implementation appeared as the prevailing goal of stakeholder involvement. Furthermore, we observed an imbalance between practice and science in output (Q23–Q33). Some projects were very practice oriented, with a strong tendency towards consultancy (P1–P3) and thus a neglected role of scientific output, which was regarded as a by-product:

> *"This was more our problem—to process and make our many insights usable which we gained through the cooperation with each other so that the practitioners are not overstrained, and on the other hand, what we have learned, let me say, as a hobby by the way to utilise. The economist and I .... because, we are the two in the network, which are still most scientifically oriented ..." (P1)*

Other projects were focussed on scientific output, which corresponded to a weak (P8 and P10) or "outsourced" (P5) practice involvement process. However, several coordinators expressed their dissatisfaction with the general scientific output of their projects (P2, P4, P7, and P10) and questioned the scientific character of TDR in general:

> *" . . . I would not say 'research'. Because I ask myself very often: where is the research now? Because in principle, only people speak to each other. So, of course, now is the question how to do something like that. But is it research?" (P4)*

Practitioners exhibited considerably different motivations and interests from those of the scientists. Their involvement in the research process was one of the main challenges (Q41 and Q43). Interview partners occasionally criticised practice partners. They complained about practice partner saturation and a resulting lack of motivation (P7), their focus on solution-based results, and their disinterest in integrated and abstract approaches (P2, P4, P8, P9, and P10). Notably, interviewees from projects who complained of disinterested practitioners were from projects that did not involve practitioners during the problem-framing phase.

4.2. Factors Influencing Adoption

4.2.1. Knowledge of the TDR Approach

Repeatedly, coordinators stated that "transdisciplinarity" remained a vague concept to them and was likely "just a new term" (P2, P4, P6, and P10) (Q1–Q10). This conceptual uncertainty is remarkable considering that the interviews primarily occurred after project completion or during the project's final stage. Four interviewees equated TDR with "applied research" (Q11–Q14) as illustrated by the following examples:

" . . . applied research—um, yes, maybe these are all words that revolve around something similar. They surely find definitions where they can clearly distinguish it. But I do not have one prepared and in my field of imagination. I believe that this is very close together and that it is rather a scientific discourse, where one tries to distinguish any nuances, . . . " (P10)

" . . . Otherwise, yes: what is transdisciplinary research? This is a new term. In Germany since 150 years we are doing applied research and so have, yes, our economic status, the reason is that we make applied research, . . . " (P4)

In general, the notion of TDR is closely connected to the feature of science–practice collaboration. However, most coordinators described TDR as the collaboration between different scientific disciplines and practice without providing further specifications regarding the qualitative aspects (knowledge integration, mutual learning).

It is apparent that the projects that met many of the TD criteria had coordinators with previous TDR project experience (P1, P6, and P7) and generally deeper knowledge of TDR. In addition, these projects expressed an appreciative attitude towards social scientific disciplines.

To gather information on TDR knowledge, we analysed the project proposals. We reviewed the proposals for criteria of TDR (*y*-axis; Table 1) and ranked each proposal on a qualitative gradient: (1) elements were frequently verbalised and explained ("mentioned as important"); (2) elements were circumscribed or labelled with comparable items ("vaguely paraphrased"); or (3) no elements were mentioned ("not mentioned").

As Figure 2 shows, a shared notion of TD as a form of science–practice–collaboration starting with a "real-world problem" was common in all proposals. Although a few proposals did not directly use the term "transdisciplinarity", it was paraphrased as "participation of practitioners". In this respect, there appeared to be basic agreement on these two general features. Remarkably, many projects distinguished interdisciplinarity from TD. Moreover, TD appeared to be conceived as an instrument of transfer, meaning the application of solutions to real-world problems from academia into practice. In general, all of the proposals revealed a common understanding of TDR as an approach for harmonising research results with the requirements of practice. Often, the claim of implementing research results was made.
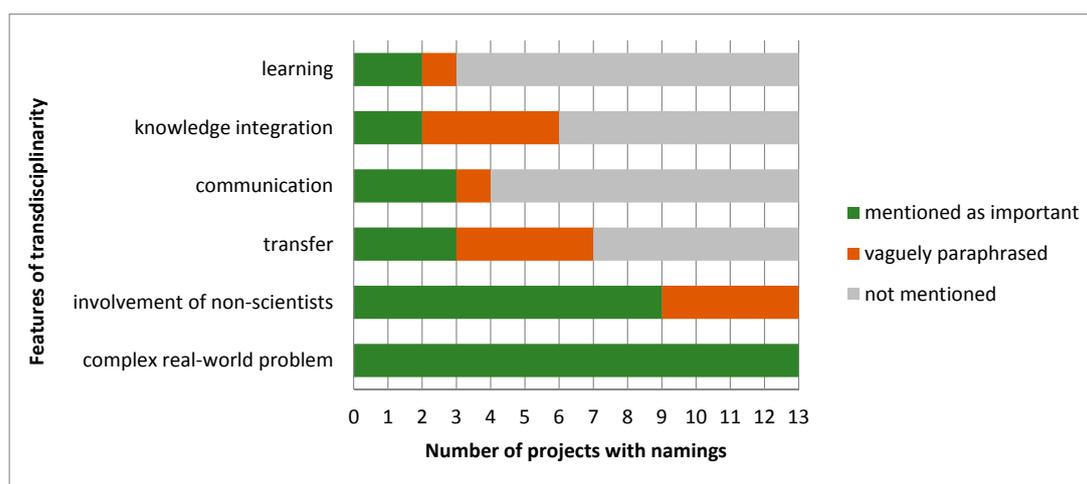

Figure 2. Inductive-based categories represented in the proposals of the 13 projects.

Few proposals explicitly targeted the creation of learning processes. The term "knowledge integration" was used explicitly only twice, and only one proposal displayed a sound understanding of the topic and, consequently, created a sub-project specifically assigned to this task. In the remaining proposals, the concept of "knowledge integration" appeared to be lacking. Where the

term "integration" was used, it was used in the context of models and data rather than as part of a comprehensive understanding.

4.2.2. Motivation and Attitude towards TDR

The interview data and responses from a workshop on TD conducted in 2012 indicated that respondents exhibited a generally positive attitude towards the TDR approach. All workshop participants (*n* = 35) declared transdisciplinary cooperation within their respective project to be "important" (*n* = 5) or "very important" (*n* = 30) to project success. However, this generally positive attitude towards TDR was not shared by all of the scientists in the projects. Several coordinators (among the senior researchers) took a very critical stance (P5, P7, and P9). They did not see any need for changing their research practice (Q37). Other researchers tended to considered TDR as an operative necessity for surpassing a specific "threshold" to secure funding.

TDR was also considered an alternative way to attract third-party funding (Q39–Q40). The interviews revealed that funding opportunities and preventing unemployment was a primary reason for starting a TDR project (P2, P3, P4, P7, and P9). In two cases, interviewees admitted that this resulted in a corresponding modification in design and wording of the proposals to meet the requirements of the application call without deeper methodological proficiency (P4 and P9).

However, we also identified a group of researchers who shifted perspectives during the course of the projects (Q38). TDR appeared to be welcomed as an opportunity to pursue and apply transformation measures (P1, P2, P3, P4, P6, and P7). Scientists exhibited a high motivation to contribute to more sustainable land use (Q44).

4.2.3. Compatibility with Academic Structures

The application call explicitly mentioned the TDR approach as an important selection criteria and precondition for achieving grants. However, TDR was not clearly defined. It was described as encompassing interdisciplinary collaboration between academics and the integration of knowledge (interdisciplinarity), in particular to join "nature scientific-technological sciences with the economic and social sciences disciplines" [50]. Furthermore, the call specified that regional "stakeholders" (decision-makers) had to be involved (TD).

Interdisciplinarity and TD were separately mentioned in the call. However, TD is not considered a broader concept that encompasses interdisciplinarity. Rather, it is used in a modular form that increases the societal relevance of research results. Regarding funding conditions, a preliminary initialising phase was neither obligatory nor supported by the funding agency. At less than four months, the period for submitting project proposals was limited, restricting the time available to collaboratively frame the problem and design the research process. One coordinator remarked on the high expenses of a developing a proposal when several researchers are involved in comparison to the moderate chances of grant success.

Half of the coordinators summarised that TDR does not "fit" into current academic structures and the scientific culture (P1, P2, P4, P5, and P10). There was doubt as to whether a project structure is the appropriate form to implement the approach and whether longer-term organisational structures are necessary. In particular, coordinators in the post-doc phase did not succeed in profiling themselves scientifically and ran the risk of opting out of academia after projects (P2, P8, and P9), which was associated with an erosion of TDR-specific knowledge.

Moreover, the management of TDR was described as especially challenging as scientists are difficult to coordinate. The specific "culture of universities" and the hierarchical leadership styles of senior scientists also complicated flexible project management. Time and resource constraints hampered effective collaborative processes, and researchers argued that funding conditions forced them towards some form of solutionism and induced science to be non-scientific.

5. Discussion

In this comparative study, one objective was to analyse how TDR is currently adopted in the field of land-use research. In addition, we aimed to identify potential influencing factors, assess their relevance for adopting the TDR approach, and consider the implications. We began with the assumption that TDR can be considered as a social innovation.

Our results show that the adoption of the TDR concept varied widely among the studied projects, as did the adoption of the TD indicators used in our analysis. On the one hand, this indicates that in research practice there are different qualities and degrees of TDR. Such a differentiation has scarcely been noted in the theoretical discourse thus far.

On the other hand, we argue that these findings also reveal a constrained adoption and implementation of TDR, which can be traced back to factors frequently discussed in the innovation literature.

5.1. There Is a Lack of Sufficient Knowledge of the TDR Concept

"Knowledge of the TDR concept" and "Previous TD experience" appeared to be the factors that most strongly influenced the quality of the transdisciplinary process. We concluded that the more extensive the background knowledge of TD (especially among the coordinating staff), the better the observed performance. This finding underlines the importance of sufficient "principle knowledge" for the innovation process [73]. However, this interpretation stands in contrast to the survey results of Tress et al. [43], who found no correlation between professional experience and the difficulties researchers face in TDR projects. However, whereas Tress et al. [43] focussed on general difficulties perceived by a broad range of researchers, the present study focused on the quality of the TDR process.

Although the coordinators generally showed a "positive general attitude" towards TDR, after 3–5 years of project experience, many coordinators possessed only a vague understanding of the TDR concept. This is remarkable, especially considering that TDR was frequently mentioned as a central feature of the projects. We speculate that this vague understanding might be due a general lack of interest in learning about TDR or a general underestimation of the complexity and corresponding requirements for the coordination of TDR projects [81].

Other scholars (e.g., Brandt et al. [82], Jahn et al. [46], Carew and Wickson [83]) noted that a lack of conceptual clarity regarding the TDR approach persists, which hampers its diffusion to other target groups. Thus, the "TD community" developed its own defined terminology, which is helpful for theoretical discussions but limits its communication to scientists in other fields [82]. Tress et al. [58] found that a lack of common understanding of TD was one major obstacle to integration. They emphasise the importance of conceptual clarity to "compare and evaluate the outcomes of different research approaches" (ibid.). Therefore, the current process of "rhetorical mainstreaming" of TDR is misguided and could marginalise researchers who seriously seek to apply TDR [40]. Thus, the integrity of TDR might be negatively affected by both a continuous degradation of the standards of TDR in practice and the increasing detachment of expert discourse from the rest of academia.

We argue that a missing common and clear definition of TDR clearly constraints its diffusion. This argument is supported by the observation that interviewees did not recognise TDR as something "new" but equated it with "applied research". Thus, it is not unexpected that these coordinators did not see any need for a change of practice.

5.2. Funding Conditions and Review Processes Require Adjustment

The vague understanding of TD was apparent as early as the research proposal stage. Many proposals showed clear weaknesses in the conceptual understanding of TDR. This finding raises questions with regard to the scientists involved in the peer-review process and their TDR expertise. Although evaluations of funding conditions often address limited time and financial resources (e.g., Maasen and Lieven [84], Tress et al. [43], Horowitz et al. [16]), the role of peer reviewers remains

widely unconsidered. In accordance with Lange and Fuest [81], we assume that the proposal reviewers were selected based on their expertise in land-use science and encountered the same difficulties in appraising the transdisciplinary concepts as did their applicant peers. As we had no access to data on the peer-review process, we cannot assess the extent to which TDR experts were included in the peer-review panel. Regardless, we argue that the involvement of TDR experts in the development of calls and the peer-review process is important for securing quality TDR. Our analysis of the programme call showed that an elaborated concept for the design and management of the transdisciplinary process was not demanded. In addition, the funding conditions limited the opportunities for collaborative framing of the research problem and for developing a common objective. The application phase was not funded, and the application time span of 4 months was very short. A lack of practice-partner involvement arising from short application phases has been documented in other studies and appears to be crucial for the collaborative process (see also Viswanathan et al. [85], Horowitz et al. [16]). More recent TDR funding programmes from the same donor have recognised this shortcoming, and a longer "framing phase" has been implemented. Further investigations are needed to determine the effects of an extended and financed preliminary phase.

However, demanding TDR as a general requirement for funding seems questionable. Such a requirement forces scientists to think in instruments, but TDR is not an end in itself. Implementing TDR should rather depend on the research question that has been posed. Hence, many of the studied projects did not meet several TDR criteria but can be regarded as valuable projects in which the research problem and objectives do not require a "full" TDR approach.

5.3. Academic Structures and Cultures Do Not Integrate Well with TDR

In general, our results showed that TDR does not easily "fit" into the established competitive academic system with its discipline-based organisational structures and reputational system (e.g., Russell et al. [86]; see also Rip and van der Meulen [87], Leydesdorff and Gauthier [88]).

Many scientists were under "high pressure for third-party funding". This pressure is prevalent within the whole scientific system and forces researchers into a continual process of proposal writing under an increasing scarcity of research funding [89]. However, the extent to which researchers can adapt to call requirements and adjust their research direction is limited as the evaluation of proposals strongly depends on prior expertise and research content. Thus, current funding mechanisms limit transitions towards new research topics and encourages researchers to engage in scientific "window dressing" [90]. Gläser and Laudel [42] regards "window dressing" as a way to "bootleg money for the start of new research under the cover of existing grants" (p. 125). Our results showed that this practice occurred in the studied projects as some coordinators reported on the "hidden research agendas" of researchers who followed their individual research interests and contributed little to the joint projects. Although our sample size was small, the large-sized projects (in terms of the number of involved project partners) appeared to be prone to this form of pretence.

Hessels et al. [89] explain the tensions that evolve for scientists when they involve stakeholders in the "credibility cycle". In addition to the pursuit of funding, the pressure to publish also increasingly rose [91], preventing scientists from reconciling the scientific demands of research with the promise of societal relevance and the involvement of stakeholders at the same time. This situation appears to be true for research fields "with less generous and powerful stakeholders" [89], as is the case in the field of land-use science. Our results showed that researchers struggled to achieve "balanced benefits" regarding practical relevance and scientific quality and productivity. Most projects were characterised by either a "primacy of practice" or a "primacy of science" [11]. In general, the scientific character and consequently the epistemic function of TDR were questioned [48].

In addition, we assume that the costs and benefits in TDR projects are not allocated in a just manner. Our investigation showed that coordinating positions are neither adequate nor recommendable for junior scientists in their post-doc phase. Post-doc coordinators carry a high load of administrative and representative duties and risk further career opportunities, likely due to a decrease in publication

output [92]. The potential loss of experienced TDR researchers for the academic system is accompanied by an erosion of knowledge and skills and hinders the development of professionalised experts who can build their careers by performing TDR. Thus, it is questionable whether a project-oriented organisation is suitable and sufficient to establish an open network structure and field practice for the development of adaptive "learning cycles" [93]. To perpetuate knowledge and many other aims, sole financing through third-party funds and the associated staff turnover should be reconsidered. Hence, the introduction of new and innovative funding instruments that support enduring structures appears necessary [7].

Another structural shortcoming appears to be the antagonism of "competition" and "cooperation". TDR as well as other collaborative research approaches such as CBPAR require inclusive and cooperative practice, whereas traditional science is a "competitive field that is exclusive" [16]. However, we found no empirical evidence for the influence of competition on the adoption of TDR in the studied projects. Rather, our results showed a disciplinary divide between social and nature-technological scientists. In several projects, social scientists had "a service role" [94] and were outnumbered. Their scientific relevance was also questioned, and some coordinators admitted to having "social scientists involved to get funding". Ledford [95] stated that social scientists are often involved in collaborative research teams to "tick a box" for societal impact but "without true commitment". Vadrot et al. [96] argued that the general underrepresentation of social scientists in science platforms dedicated to global challenges, such as IPBES (The Intergovernmental Platform on Biodiversity and Ecosystem Services), "mirrors institutional and knowledge barriers between research disciplines". In contrast, Van Langenhove [97] emphasised the importance of social scientists for addressing global challenges and recognised "reluctance" on the part of social scientists to do so.

6. Conclusions

The aim of this comparative study was to analyse how the challenging approach of TDR is adopted in 13 TDR projects over a period of five years. The projects covered the field of land-use research performed under similar conditions (same funding programme). In addition, we aimed to identify potential influencing factors to assess their relevance for adopting the TDR approach and to consider implications. Results are based on the analysis of interviews with coordinating researchers, project proposals, reports, web pages, protocols and field notes during meetings. We began with the assumption that TDR can be considered a social innovation in academia that is currently in the critical stage of up-scaling from a small TDR-advocating expert community to a broader science-practice community.

Our results show that the adoption of the TDR concept varied widely among the studied projects, as did the adoption level of the TDR indicators used in our analysis:

(1). Only few projects strived to achieve a process of collaboratively framing the research problem and defining the objectives involving actors from practice at the initial project phase.

(2). Interdisciplinary collaboration exhibited a prevailing additive character. The integration of conceptual frameworks and theory from different disciplines was frequently not strategically planned or managed.

(3). The dominance of natural scientific-technological disciplines was apparent in many cases. In many of the studied projects, social scientists were not only outnumbered but also regarded as a "service discipline".

(4). In a minority of projects, science-practice collaboration had a central role and was designed as a process with equal footing. In many projects, information transfer and consultation events outweighed more integrative approaches.

On the one hand, this indicates that in research practice there are different qualities and degrees of TDR, which has scarcely been noted in the theoretical discourse thus far. In addition, there are no minimal standards yet to distinguish between a TDR project and a non-TDR project.

On the other hand, we argue that these findings also reveal a constrained adoption and implementation of TDR, which can be traced back, among others, to:

(1). a lack of knowledge among a broader community of scientists who apply TDR;
(2). dysfunctional funding conditions; and
(3). contradicting academic structures and cultures.

Even if our results only present a medium sample of projects from the specific field of land-use science and acknowledging that empirical studies from other research fields are needed to prove our findings, we conclude that the idea of TDR is based on expert-driven discussion and concept development, which have not yet been diffused and adopted by a broader community.

Thus, the findings imply that in addition to further communication and educational efforts, novel funding instruments that support sustained structures are needed to promote TDR. These structural changes appear especially important as current adoption practice bears the risk of improper characterisation, implementation, or evaluation of the TDR approach. As a result, a persistent underperformance of TDR may cause its discontinuance and hinder its establishment as a well accepted research approach in academia.

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