2 History and mapping of transdisciplinary research on sustainable development issues

Dealing with complex problems in times of urgency

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2.1 Introduction

Transdisciplinarity as a research approach is widely recommended for addressing sustainability issues. Transdisciplinary research practices have emerged in 'sustainability science' as an integrating field of science, as well as in a wide range of disciplines contributing to the analysis and problem solving of the many interrelated issues covered by the concept of sustainable development. These issues include climate change, loss of biodiversity, resource depletion, human health impacts, inequality in labour conditions and distribution of wealth, poverty and societal instability (for more detailed discussion on the concept of sustainable development, see Vermeulen, 2018).

This chapter briefly shows the history of the concept of transdisciplinarity. First, from a wider perspective, it discusses the emergence of the concept of transdisciplinarity in various disciplines. Second, it shows how it has been adopted in the field of sustainability sciences as a core research approach needed to address the persistent and urgent challenges mankind is facing.

Sustainability science itself has been developed as an interdisciplinary field of research addressing the complex nature–society metabolism: human society exploiting social and ecological resources without precautionary attention for the direct, indirect and long-term impacts of this (Vermeulen, 2018). Sustainability sciences, which can be seen as the joint mobilization of insights picked from all relevant branches of the 'tree of wisdom', combine knowledge from the fields of environmental studies, development studies and all available basic disciplines in natural and social sciences. It emerged at the beginning of the 21st century, stressing the sense of urgency of the various persistent sustainability issues, which had previously been studied more in isolation (Kates et al., 2001; Kates, 2002; Parris and Kates, 2003).

Within the context of the second United Nations conference on sustainable development in Johannesburg in 2002, the link was made with an earlier and wider development of scientists calling for academic work to better connect to societal needs, now also framing sustainability sciences as essentially a form of 'transdisciplinary research' (Daschkeit, 2006; Potschin and Haines-Young, 2006; Jerneck

et al., 2010). In the same period, many scientific disciplines developed specialized streams of research addressing sustainability issues as well.

The concept of transdisciplinarity goes back to the 1960s and earlier (Miller et al., 2008; Jahn et al., 2012). One of the original publications on this, by the Austrian-American Erich Jantsch, stressed the need for collaborative forms of science which successfully contribute to solving societal issues, or as he phrased it in those days: adapting universities 'as a means of increasing the capability of society for continuous self-renewal' (Jantsch, 1970, 1972, p. 12). Jantsch introduced the concepts of multidisciplinarity, pluridisciplinarity, crossdisciplinarity, interdisciplinarity and transdisciplinarity in the context of critical debates in sociology of science/philosophy of science on the role of universities in society. This early debate on transdisciplinarity focused on the need to create collaboration between natural sciences, social sciences and humanities and justified the normative approach in scientific work and 'education for self-renewal'. But for a long time, this debate was mostly an intra-academic debate among scientists reflecting and debating their scientific practice. They stressed the need for collaboration for system thinking within sciences, which was first established in so-called more purpose-oriented fields of social sciences (like policy science, urban planning and the earliest programmes addressing environmental problems) (Jantsch, 1970, pp. 416–421). Transdisciplinarity in this context was described as 'coordination of the whole university system toward a common goal' (Jantsch, 1970, p. 413), without any reference to connecting to societal stakeholders yet, rather addressing university administrators.

In this early context, transdisciplinary research was defined as 'the coordination of all disciplines and interdisciplines in the education/innovation system on the basis of a generalized axiomatics (introduced from the purposive level) and an emerging epistemological pattern' (Jantsch, 1972, p. 16). With this emphasis on higher level understanding of complex phenomena, academic education was framed as 'essentially being an important, or even the most important agent of innovation' (Jantsch, 1972, p. 12). In this sociology of science/philosophy of science debate, Jantsch refers to the developmental psychologist Piaget, who in those days introduced the views on four levels of understanding. The fourth-highest level was the 'derived epistemological' level, which was described as 'where all sciences are related to each other, where a generalized epistemology begins to emerge, and where approaches can be unified on the basis of a generalized axiomatics' (Jantsch, 1972, p. 17). In this sense, transdisciplinarity was originally seen as an intra-academic practice: scientists with an understanding at the highest level are delivering the needed societal change. As expressed in Figure 2.1, transdisciplinarity was in these early days about organizing knowledge creation at the most-inclusive epistemological level for the purpose of bringing progress to society. Figure 2.1 shows that scientific knowledge creation addresses both the physical world and the social world. The diverse scientific community, with its main disciplines, is shown as the circle in the middle; the natural sciences are shown at the left and the social sciences and humanities more to the right. The various (mono-)disciplines all separately focus on certain aspects of the real-world phenomena related to the physical and the social world.

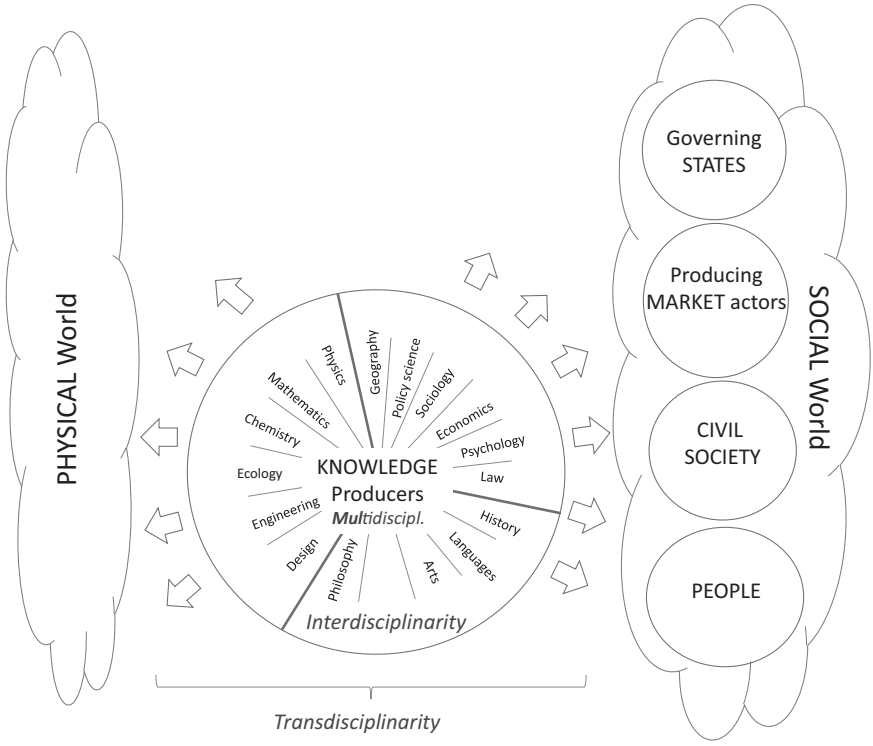

Figure 2.1 Various approaches in connecting scientific disciplines: mono-, multi-, inter- and transdisciplinarity

Multidisciplinarity refers to the connecting knowledge in approaching an issue, using various perceptions of a range of disciplines, while each discipline works in a self-contained manner with little cross-fertilization among disciplines, or synergy in the outcomes. Interdisciplinarity refers to a form of coordinated and integration-oriented collaboration between researchers from different disciplines (Hirsch Hadorn et al., 2008, pp. 428–429; Mauser et al., 2013).[1] In this way, multi- and interdisciplinarity refer to increasing levels of collaboration, while in the view of Jantsch, transdisciplinary research includes the creation of a useful unifying theory. This can be called 'intra-academic transdisciplinarity'.

After these early views, discourses on transdisciplinarity have emerged slowly, in many different disciplines, all oriented towards contributing to solving persistent societal problems. There is a stronger uptake of the concept after the change of the millennium, resulting in more than 12,600 publications (in Scopus) through the end of 2018 (see Figure 2.2).

As mentioned earlier, various social sciences, including psychology and humanities, comprise the largest group adopting the concept (see Figure 2.3), reaching out to their 'research objects' with many forms of 'action research', some also

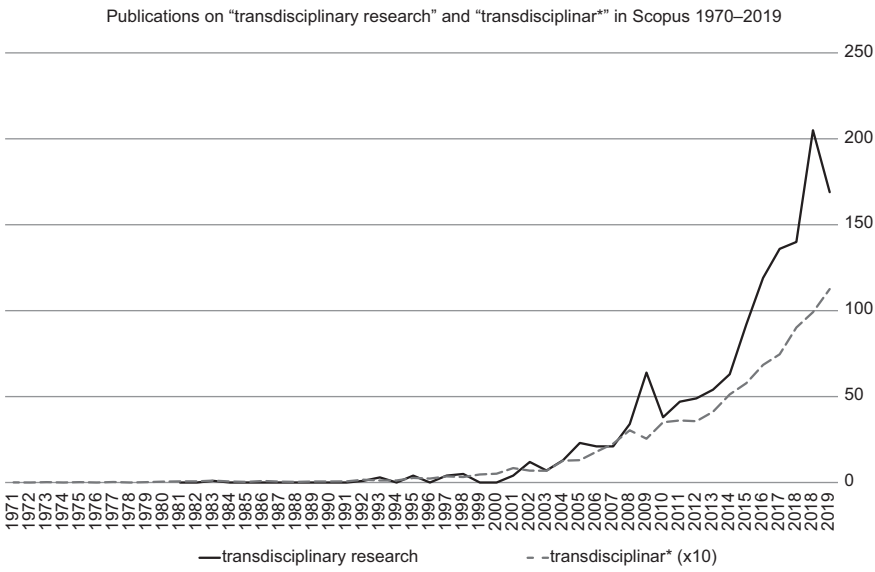

Figure 2.2 Publications on ‘transdisciplinary research’ and ‘transdisciplinar*’ in Scopus 1970–2019

aiming towards empowerment of weaker groups in societies (MacDonald, 2012). The third largest group of researchers is in health-related disciplines where close engagement with users of medical solutions has been elaborated as a form of transdisciplinary research. Also, business and organization-oriented researchers have been active in transdisciplinary forms of research. But the field of sustainability-related sciences is the second largest group in producing such research work (this category includes the Scopus subject areas of energy, environmental science, agricultural and biological sciences and earth and planetary sciences in Figure 2.3).

2.2 The historical development of transdisciplinarity

Zooming in on scholars in sustainability-related sciences, one can see the top ten researchers (see Table 2.1), who are for the most part closely connected and also often publish together.

Transdisciplinarity’s take-off occurred in the first decade of the 21st century, when various books, workshops and conferences set the scene, including the International Transdisciplinarity 2000 Conference organized by ETH Zürich (Klein et al., 2001; Jahn et al., 2012) and a special symposium within the International Sustainable Development Research Society’s (ISDRS) annual conference in June 2005 in Helsinki, resulting in a special issue (Posch and Scholz, 2006; Scholz et al., 2006; Wiiek et al., 2006). The Swiss government strongly supported the development of transdisciplinary research during this period. All of these activities

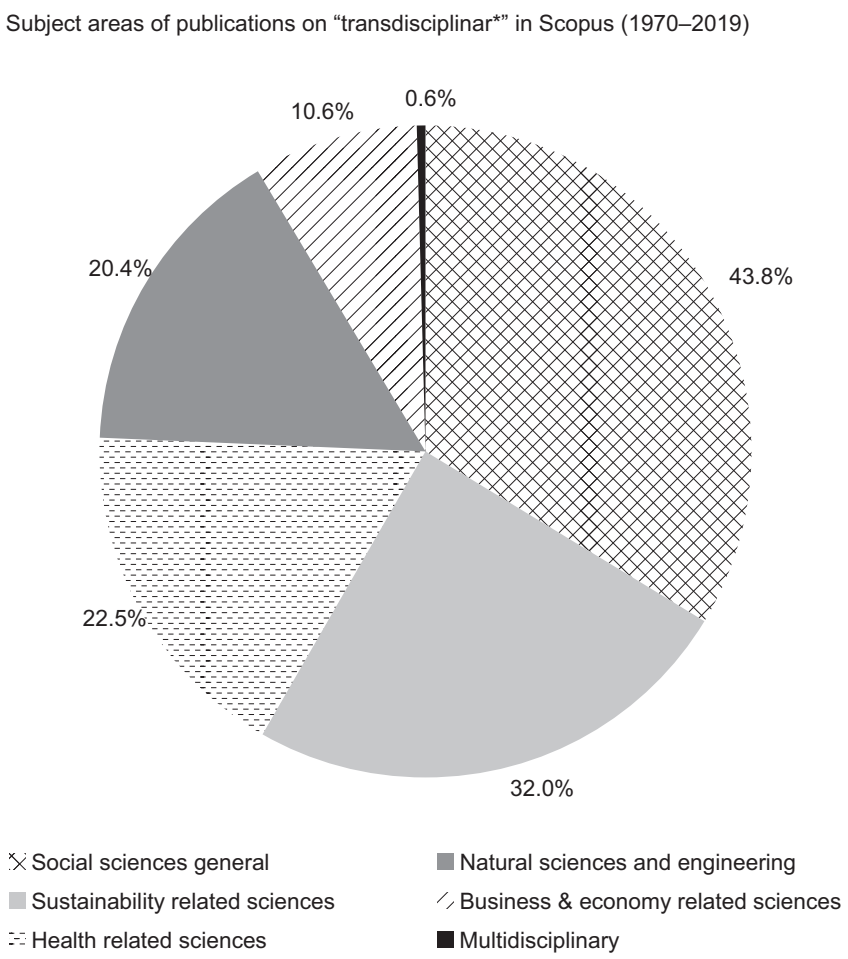

Figure 2.3 Subject areas of publications on 'transdisciplinar*' in Scopus (1970–2019)

have built very strongly on ideas brought forward in the 1990s by sociologists and philosophers of science regarding 'mode 2 science' (Gibbons et al., 1994; Gibbons, 1999; Gibbons and Nowotny, 2001) and 'post-normal science' (Funtowicz and Ravetz, 1994a, 1994b), discussed in section 2.3.

In this period, this earlier intra-academic discourse started to meet practitioners of new transdisciplinary forms of research. Some claim that the take-off of transdisciplinarity is also rooted in the emerging practices of collaborative, open policy and 'co-production' programmes in countries like Switzerland, Denmark and the Netherlands in this period (Thompson Klein, 2004, p. 517), which will be discussed in section 2.3. Table 2.1 shows the main authors in the field and the topics they have examined, partly on the methodology and its implications and

Table 2.1 Top 10 authors in Scopus on transdisciplinarity in the field of sustainability sciences

Rang	*Name*	*Institution*	*# of articles*	*Some main publications*	*Topic area*
1	Scholz, R.W.	ETH Zurich, Switzerland	47	(Laws et al., 2004; Scholz et al., 2006; Sell et al., 2006; Walter et al., 2007; Hansmann et al., 2009; Shiroyama et al., 2012; Yarime et al., 2012)	Methodology of transdisciplinarity; cases in higher education; cases on innovation, forestry, phosphorous
2	Pohl, C.	ETH Zurich, Switzerland	30	(Pohl, 2005, 2008, 2011; Hirsch et al., 2006; Pohl and Hirsch Hadorn, 2007, 2008a; Hirsch Hadorn et al., 2008; Pohl and Hirsch Hadorn, 2008b; Pohl et al., 2010; Wuelser et al., 2012)	Methodology of transdisciplinarity; cases in low income countries
3	Lang, D.J.	Leuphana University of Lüneburg, Germany	29	(Scholz et al., 2006; Lang et al., 2012; Brandt et al., 2013; Withycombe Keeler et al., 2016)	Methodology of transdisciplinarity; cases in higher education
4	Stauffacher, M.	ETH Zurich, Switzerland	24	(Scholz et al., 2006; Lang et al., 2012; Groß and Stauffacher, 2014)	Methodology of transdisciplinarity
5	Wiek, A.	Former ETH Zurich, Switzerland, Arizona State University, USA	19	(Scholz et al., 2006; Walter et al., 2007; Brundiers et al., 2010; Wiek et al., 2011; Lang et al., 2012; Wiek and Iwaniec, 2014; Withycombe Keeler et al., 2016)	Methodology of transdisciplinarity; cases in higher education; impacts of transdisciplinary research
6	Fam, D.	University of Technology, Sydney, Australia	14	(Lopes et al., 2012; Fam and Mitchell, 2013; Mitchell et al., 2015)	Methodology of transdisciplinarity; cases in water management and sanitation
7	Bouma, J.	Wageningen University, NL	13	(Bouma, 2015)	Cases in agricultural sciences
8	Mitchell, R.C.	Brock University, St Catharines, Canada	13	(Carew and Mitchell, 2008; Mitchell and Moore, 2015; Mitchell et al., 2015)	Methodology of transdisciplinarity; cases in water management and sanitation; pedagogy
9	Moore, S.A.	Brock University, St Catharines, Canada	13	(Mitchell and Moore, 2015)	Methodology of transdisciplinarity; cases in higher education; social sustainability; pedagogy
10	Schäpke, N.	Leuphana University of Lüneburg, Lüneburg, Germany	13	(Wittmayer and Schäpke, 2014; Schäpke et al., 2018)	Methodology of transdisciplinarity; cases in sustainable energy

partly presenting examples of its application in the context of various societal challenges. The table shows that many of these scholars are engaged in working towards a shared and elaborated methodology and demonstrates this with examples of various sustainability issues while also reflecting on the new forms of higher education teaching needed for this.

One needs to be careful with this approach of identifying key authors via Scopus, as it may be biased towards richer countries, with their strong academic practices oriented towards journal publication. There are many efforts to position science as a change-maker in African and Latin-American contexts which are not visible through this approach (Hall, 1992, 2005), since little evidence of this can be found by means of an English language-based literature review with Scopus or Web of Science.

2.3 Defining transdisciplinarity

Transdisciplinary researchers in sustainability sciences do not all present the same definitions and practical methods, but a clear common line in the transdisciplinary approach can be identified. It builds on ideas about 'mode 2' and 'post-normal' science. In the first published handbook in this field, Pohl and Hirsch Hadorn stated that transdisciplinary research is needed

> when knowledge about a societally relevant problem field is uncertain, when the concrete nature of problems is disputed, and when there is a great deal at stake for those concerned by problems and involved in dealing with them. Transdisciplinary research deals with problem fields in such a way that it can: (a) grasp the complexity of problems, (b) take into account the diversity of life-world and scientific perceptions of problems, (c) link abstract and case-specific knowledge, and (d) develop knowledge and practices that promote what is perceived to be the common good.
>
> (Pohl and Hirsch Hadorn, 2007)

Also see Hirsch Hadorn et al. (2008), p. 432; Stock and Burton (2011), and in a comparable mode, Lang et al. (2012), pp. 26–27.

This description contains three elements common to the debate on transdisciplinarity, bringing together three major ambitions for scientists who intend to engage universities 'as a means of increasing the capability of society for continuous self-renewal', as cited here. These ambitions relate to challenges of *pluralistic scientific and non-scientific knowledge creation* at a high level of integration; to addressing the features of *'messy' societal problems*; and to dealing with the *urgency and persistency* of (sustainability) challenges. Figure 2.4 illustrates the wider background behind these three ambitions, which will briefly be discussed.

Developments in modes of knowledge production have been fuelled by authors like Jantsch (mentioned earlier) in the 1970s and Gibbons, Funtowicz and Ravetz in the 1980s and 1990s (Funtowicz and Ravetz, 1994b; Gibbons et al., 1994).

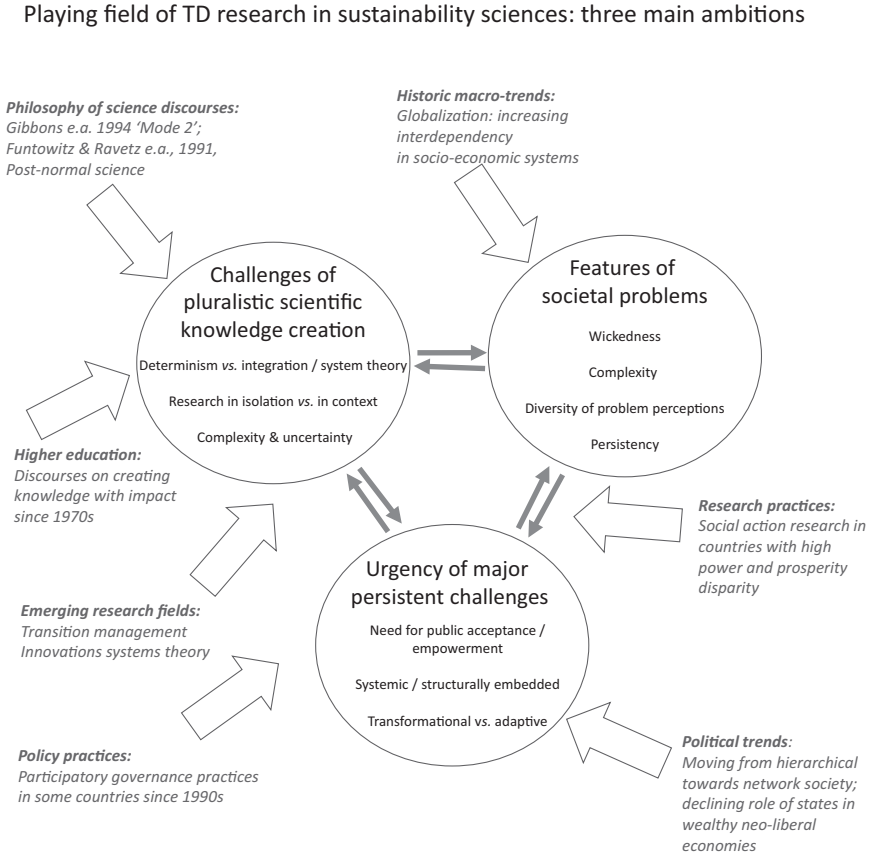

Figure 2.4 Playing field of transdisciplinary research in sustainability sciences: three main ambitions (in black/background sources in blue, italic)

The challenges of *scientific knowledge production* have been stressed by Gibbons, Nowotny and others with 'mode 2 science' – the problem-oriented and interdisciplinary nature of knowledge production in contrast to traditional theory and curiosity-led fundamental knowledge production (Gibbons et al., 1994; Nowotny et al., 2003). They also observed that science is no longer the single domain of academia: many other 'knowledge producers' are playing an essential role in making knowledge useful for societal actors like government and industry. Simultaneously, they argued that the growing role of government funding and industry-oriented research (in the triple helix of nation-state, academia and industry; Etzkowitz and Leydesdorff, 2000) would better explain the development in science and innovation than the orientation on traditional, fundamental and disciplinary 'Mode 1' knowledge production. Such problem-oriented forms of applied

research have been growing both inside and outside universities (research institutes, consultancy etc.). Gibbons et al. framed 'mode 2' explicitly as transdisciplinary, with three main features: 1) problem-solving orientation: having its own practice-related research approaches; and as result of that, 2) communication of results going beyond the (disciplinary) scientific arena, addressing practitioners involved; and 3) different dynamics in its application outside specific disciplines (Gibbons et al., 1994, pp. 4–7). They explicitly refer to the original 'universal theory' ambition of Jantsch and others and observe that such attempts only survived in small scientific niches. They contrast their use of the concept of transdisciplinarity as 'continuous linking and re-linking, in specific clusterings and configurations of knowledge which is brought together on a temporary basis in specific contexts of application' (Gibbons et al., 1994, pp. 27–30), mainly in science and technology-related research fields. Stakeholder involvement is explicitly pursued in their publications for the purpose of getting better shared knowledge.

Funtowicz and Ravetz introduced the concept of 'post-normal science', adding another element to this observed diversity of knowledge producers and practices: the nature of complex problems in practice requires new ways of assessing solutions, especially in the areas where science and policy meet. Responding to traditional forms of risk assessment, they call for new forms of communication about uncertainty and quality assessment, and suggest new forms of extended peer communities (Funtowicz and Ravetz, 1994a, 1994b).

Simultaneously internationalization and globalization of the economic system has contributed to the increasing *complexity of societal problems*. Policy makers are confronted with issues on which stakeholders' views differ fundamentally. They respond from different value sets and worldviews. Solutions for these issues often mutually affect each other, while they are often beyond the scope of power of individual policy makers at national or lower levels of government. These issues are described in the literature with various concepts: 'complex problems', 'messy problems' or 'wicked problems'. They have gained increasing attention in policy science, urban planning, management and design (Rittel and Webber, 1973; Ackoff and Vergara, 1981; Pacanowsky, 1995; Waddock, 1998) as problems for which a purely scientific–engineering approach cannot be applied because of the lack of a clear problem definition and differing perspectives of stakeholders and value judgements (Schwarz and Thompson, 1990).

This view on the nature of sustainability problems has also resonated in many policy projects, starting, in various contexts, in the late 1980s/1990s. One of the key messages for addressing wicked problems has been to engage stakeholders with conflicting interests in the process of policy development and formulation from the start, in so-called open or interactive policy making. Connected to those policy innovations, scholars like Susskind et al. and Friend and Hickling have been actively collaborating in policy making on environmental topics in both the USA and various European countries: they have designed flexible approaches for working in multi-stakeholder settings, collectively engaging in joined problem analysis, creating shared problem perceptions and leading this towards collaborative problem solution (Friend and Hickling, 2005) (see also Acland, 1995;

Healey, 1997; Vermeulen et al., 1997; Susskind et al., 1999). Simultaneously, various scholars (Checkland and Scholes, 1999; Lawrence and Deagen, 2001; Kasemir, 2003; Schwarz, 2005; Kaner et al., 2014) have developed practitioner guides describing collaboration processes as sequences of, first, jointly describing the issue at stake from a diversity of perspectives; and second, integrating these views in a holistic system view, allowing for key causes and connected routes to solutions to be searched for, after which solutions are jointly evaluated and decision-making on implementation is prepared.

In the field of policy science, this has stimulated a special branch of research on participatory policy making, co-production policy, co-creation, open planning, self-governance and interactive governance (OECD, 2001; Singleton, 2002; Abelson et al., 2003; Bulkeley and Mol, 2003). Here the existence of wicked problems is also connected to distributed power of decision-making between actors within organizations or in inter-organizational settings. The practices of participatory policy making have attracted a large deal of attention and critical evaluation research (Steelman and Ascher, 1997; Driessen et al., 2001; Vermeulen, 2002; Bingham et al., 2005). Some of the criticism relates to the observation that creating shared policy agendas in multi-stakeholder settings often still lacks the power of final decision-making and full implementation of the results of such processes (Coenen et al., 1998; see for example Busenberg, 2000).

Such multi-stakeholder governance has been applied in many sub-fields of environmental policy making, also linking it to long-term-oriented innovation policies in which scenario development and long-term planning are combined. By applying methodologies like backcasting, consensus conferences, citizen juries and more (Armour, 1995; Dreborg, 1996; Fixdal, 1997; Faucheux and Hue, 2001; Cuhls, 2003; Quist and Vergragt, 2006), scientists have acted both as knowledge providers and as process architects in joint settings with governmental and societal stakeholders. Some of these practices have addressed extremely complex issues, including sustainability issues on the global scale, such as a global multi-stakeholder project on phosphorous management (Scholz et al., 2013). These participative and anticipatory approaches have also been addressed in the field of management studies (Robinson, 2003; van de Ven and Johnson, 2006).

With increasing upscaling and complexity of sustainability problems, some scholars recently introduced the concept of 'super wicked problems' (Lazarus, 2013). This special class of wicked problem has been described by adding the *notion of urgency*: describing them with four key features: 1) time is running out; 2) those who cause the problem also seek to provide a solution; 3) the central authority needed to address them is weak or non-existent; and 4) irrational discounting occurs that pushes responses into the future (Levin et al., 2012). This feature of urgency is especially relevant in the field of sustainability, where decades of international policy attention have not yet brought the major transitions that are required. On a global policy level, the United Nations framed sustainability as the programme to address persistent environmental problems, reducing still-increasing inequalities and growing ecological, climate and health threats in a

context of growing conflicts and stating that 'we are determined to take the bold and transformative steps which are urgently needed to shift the world on to a sustainable and resilient path' (United Nations, 2015, pp. 5, 8). Comparable global reports stress the same sense of urgency in the areas of climate changes (IPCC, 2014), inequality (Alvaredo et al., 2017), biodiversity (Secretariat of the Convention on Biological Diversity, 2014) and more.

In summary, the three main ambitions inspiring transdisciplinary researchers require them to balance challenges of *scientific knowledge creation* with a high level of integration, while addressing *'messy' societal problems* and also dealing with the *urgency and persistency* of (sustainability) challenges. Transdisciplinary scholars work with diverse combinations of attention for these foci. To use a culinary metaphor, this results in various '*tastes*' *of transdisciplinarity*, adding different doses of these components to their research projects. These tastes can mainly be distinguished by which groups of stakeholders are invited to the 'research table'.

Some scholars focus mostly on *complexity issues* in sustainability sciences and possibly still pursue a unifying theory (Jantsch, 1972; Max-Neef, 2005; Mittelstrass, 2011; Nicolescu, 2012; Mitchell and Moore, 2015), with some engaging in complex modelling. This first group shares the idea of building 'better' models and a higher-level understanding and of enabling the production of future scenarios which allow for (participatory) policy formulation (Rotmans, 1998; Quist and Vergragt, 2006). This 'vintage' taste can be called *intra-academic transdisciplinarity* and also relates to interactive technology foresight. Here, the stakeholder involvement is limited and instrumental, aiming at creating better models (theoretical or used for forecasting and scenario building). Stakeholder involvement is mostly restricted to industrial representatives, sometimes adding civil society organizations, but rarely citizens.

Other scholars stress problem solving and implementation support, closely linked to local, regional, national and sometimes even supranational policy making: this taste can be described as *solution-driven transdisciplinarity*. Also, the in the emerging field of transformational governance and transition management (Smith et al., 2005; Kemp et al., 2007; Geels, 2012; Feola, 2015), stakeholder involvement is more extended – mostly civil society, often industrial representatives, sometime individual citizens.

A third group of scholars stresses empowerment and the need to combat persistent and urgent (social) sustainability issues; for this, they claim that inclusion of non-academic knowledge sources is needed. Some call it transgressive social learning (Lotz-Sisitka et al., 2015). It partly builds on a longer tradition of participatory action research and pedagogy of the poor (Freire, 1970) or, more recently, 'emergent transdisciplinarity' (van Breda and Swilling, 2018). This taste can be labelled as *fairness-driven transdisciplinarity*. Stakeholder involvement here, more than in the other tastes, stresses the involvement often weakly represented citizens and their networks in civil society, while including policy makers but far less often market actors.

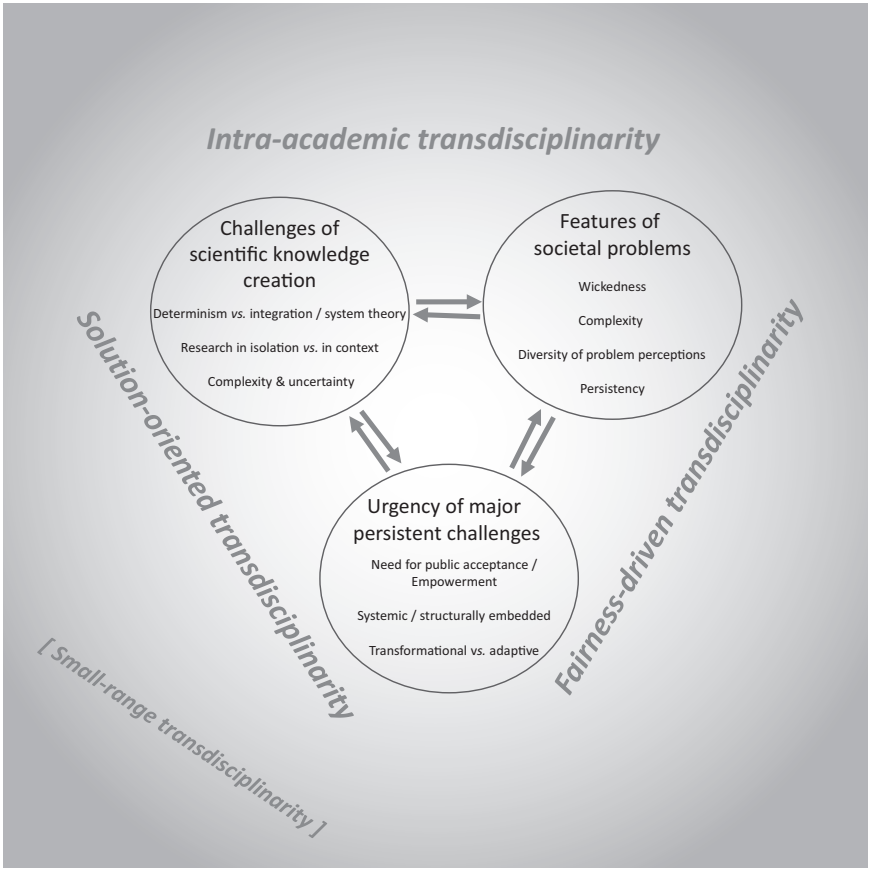

Figure 2.5 Playing field of transdisciplinary research in sustainability sciences: three tastes of transdisciplinarity (+small-range transdisciplinarity)

Using the Figure 2.4, the three 'tastes' can be presented as in Figure 2.5, illustrating that these tastes of transdisciplinarity represent different combinations of ambitions, with differences in aspirational foci. The core of this figure is white and the corners are grey, to indicate diversity in practice, depending on the extent and diversity of non-academic stakeholder involvement in the research process. At the grey borders of the figure would be projects with only few academic and non-academic stakeholders, as in many consultancy projects (small-range transdisciplinarity).

In practice, the concept of transdisciplinarity is used in many cases with weaker connections to the scientific views and ambitions described earlier, but where some form of outreach from academia to users of knowledge and their products exists and is taking place, in more traditional consultancy or client-driven applied research work (see Hirsch Hadorn et al., 2008, p. 33, for an

useful distinction). In such cases, the problem is not as wicked, messy or complex as suggested in the literature discussed previously, and the scope of stakeholder involvement can also be very limited. However, in line with increasing attention by funding agencies for research impact and 'research utilization', they often require direct collaboration with market actors, governments or civil society actors. This taste of transdisciplinarity can be described as *small-range transdisciplinarity*. It links explicitly to the knowledge needs of (some) non-academic actors but is often less complex, less ambitious and less stakeholder-inclusive; even though it may address societal needs, it lacks explicit empowerment ambition. In practice, research funding agencies (on both a national and also supranational level, like EU Horizon 2020) increasingly demand impacts in society, but in the funding application procedures still require very detailed project proposals; these form a barrier for open transdisciplinary research processes, where the research question and approach are part of the process. This leads to serious limitations for transdisciplinarity-oriented researchers (Mitchell et al., 2015; De Jong et al., 2016; Gaziulusoy et al., 2016; Zscheischler et al., 2017)

The main differences between the three tastes are in how, and to what extent, stakeholder involvement is required and organized: that is, what roles are given to stakeholders in the research process.

Comparable classifications of transdisciplinarity are also available in the transdisciplinarity literature. Pohl et al. described three forms of transdisciplinarity which they call 'A', 'B' and 'C' (Pohl, 2011, p. 611). Popa et al. presented a matrix to describe various forms (Popa et al., 2015, p. 250). Max-Neef used a dichotomy, distinguishing strong and weak transdisciplinarity (Max-Neef, 2005). Finally, Balsiger distinguishes between 'soft', 'hard', 'reflexive' and 'inclusive' (Balsiger, 2015).

We can combine these classifications and clarify how they relate to the three tastes by adding in the stakeholder engagement elements. For this, the matrix of Popa et al. (2015) serves as a starting point; in Figure 2.6, an underlying matrix is added to describe the stakeholder engagement.

Using the synthesis of transdisciplinarity discourses in Figure 2.6, the scientific discourse on transdisciplinarity and sustainability can be visualized as moving from the left top corner more towards the bottom right corner, responding to the persistent nature of sustainability issues and the growing need for urgent transformative change. Common elements in the current approaches to transdisciplinarity can be identified, based on what transdisciplinary authors in the right and bottom part of the figure have presented as overall 'architecture' of transdisciplinary research processes. One of the main points of consensus is that no standard set of methods can be described. The key nature of joint knowledge creation for problem solving of sustainability challenges does, according to various scholars, explicitly require flexibility and context adaptiveness in the choice and application of research methods. These schools of researchers proposed methods and tools for the four mains steps in a 'diabolic' process: stakeholders first jointly engage in problem structuring, then proceed in joint systems analysis; this continues with a search for solutions and results in preparing for the application

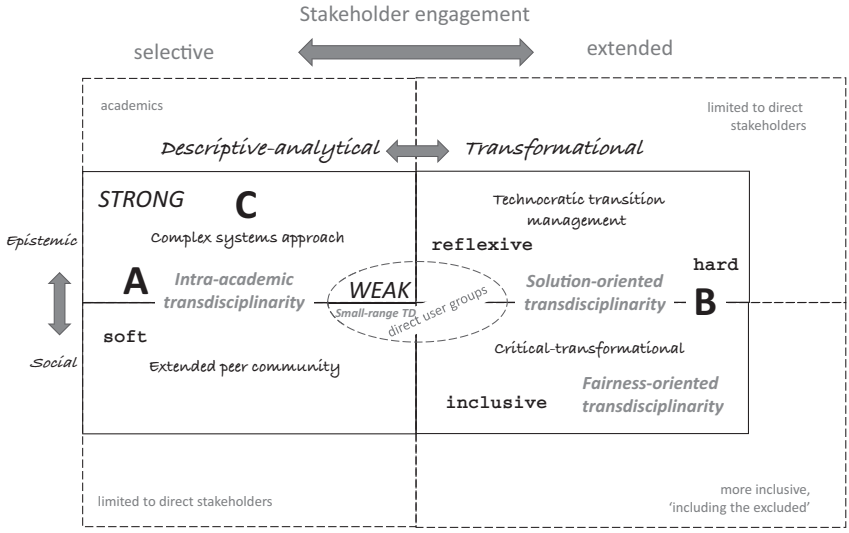

Figure 2.6 Playing field of transdisciplinary research in sustainability sciences: synthesizing typologies of transdisciplinarity (concepts described in text)

of jointly agreed solutions. During these steps, one moves backwards and forwards whenever needed for better understanding or better outcomes (Chapter 3 will further reflect on this). It is essential that the right side of the playing field, as mapped in Figure 2.6, stresses more inclusive and diverse forms of collaboration with non-academic stakeholders.

The next chapter will look more closely at the methods for transdisciplinarity, identifying the main principles (such as multi-actor involvement; iterative design; focus on wicked problems; using abductive reasoning; multi-level learning) and suggesting methods that can be applied for stakeholder engagement to deal with multiple perceptions, worldviews, value systems, collective ideation, selection and choice making.

Note

1 Others also use 'supra-disciplinarity' for all forms of scientific collaboration where the field of a single discipline is transgressed (Balsiger, 2004), or 'super-disciplinarity' while in fact referring to what elsewhere is labelled as interdisciplinarity (examples are Jones, 2009; Anatolevich and Vasilyevna, 2018; Li et al., 2020).

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