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Socially responsible research processes for sustainability transformation: an integrated assessment framework

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Assessing the manner in which research is conducted is a key mechanism for leveraging a transformation in sustainability. Scientific answers to current sustainability threats are reliant on research design, conduct and dissemination. Thus, the research process itself merits a full consideration of its responsibility toward societal goals and values. Although the responsibility of research to society has recently been raised in scientific discourse, a systematic framework to guide such considerations that can be applied in a self-reflective manner across disciplines is lacking. Informed by a literature review that revealed an emerging discussion, this paper suggests an assessment framework for socially responsible research processes that integrates eight criteria: (1) approach to complexity and uncertainty, (2) ethics, (3) interdisciplinarity, (4) integrative approach, (5) reflection on impacts, (6) transdisciplinarity, (7) transparency and (8) user orientation. These criteria, including their respective linkages and ambivalent meanings, are elucidated. Implementation challenges, application trade-offs and opportunities with respect to an enhanced shift toward societal responsibility in research processes are discussed.

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Introduction

We seek to promote that one mechanism leveraging sustainability transformation is the reflection on and assessment of research processes from the perspective of societal responsibility. We generally understand sustainability transformation as a fundamental long-term development of society toward enhanced human well-being built on environmental accountability and protection [1,2], as recently agreed on in the Sustainable Development Goals of the United Nations [3] and addressed in the Future Earth Initiative [4] and the EU's Grand Challenges [5]. Research processes or research conduct are defined as all activities involved in the execution of research and generation of knowledge. Research can be structured in different phases, including setting agendas, selecting research topics, designs and methods, analyzing and communicating data and results and generating adapted research agendas and research questions based on previous research results.

A reflection on how research processes affect societal development and goals such as sustainability transformation is at the core of science's responsibility to society [6–12]. The customary scientific integrity of research processes [13–15], which focuses on, for example, competence and honesty in the treatment of scientific methods, generation of accurate and reliable data and fairness in the publication process faces additional requirements and requests. For example, the epistemologically valid generation of research results might have either expected or unexpected socially reprehensible consequences, such as research on genetic modifications or the development of new technologies and materials mainly used for economic or military purposes [16]. The results of such research may also be misused or exacerbate societal concerns. Scientific reflection concerning how a particular type of research could benefit or harm society would help identify the best solutions to societal challenges. Thus, discussions on the scope and content of social responsibility and moral accountability by researchers have been facilitated in the literature and by international research networks [17–20].

Within the emerging scientific debate on opening up established knowledge systems and implementing new research standards from the perspective of societal responsibility, two scientific fields are notable. First, the field of sustainability science aims at making knowledge usable within science and society to secure human needs while preserving the life-support systems of the earth [21,22]. By definition, this scientific field has a strong

societal perspective and a commitment to societal responsibility. Studies have also called for more reflexive inquiry and a change in the research process itself. This must be immersed in the processes of decision making for societal transition and adaptation to build socially robust knowledge [23–27]. Second, originating from the scientific field of technology assessment, the Responsible Research and Innovation (RRI) initiative emphasizes planning, justification and impact assessment of implemented technologies in light of societal responsibility (e.g., [28,29]).

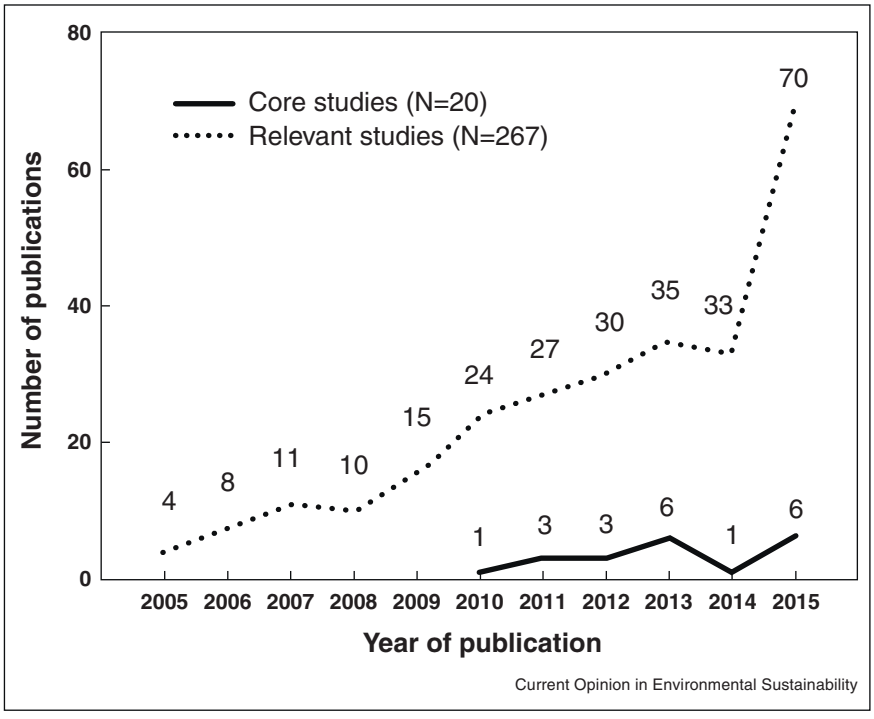
Despite these progressive approaches from sustainability science and RRI to frame relevancy and characterization of socially responsible research processes, a framework that integrates discussions of societal responsibility from all scientific disciplines remains to be developed. For example, the demands of sustainability and societal responsibility have not been fully merged into other disciplines, as for example Scheirer and Dearing criticize in public health research [30••]. In addition, a common knowledge or understanding among scientists of how to address societal responsibility in research processes and assessments has not been made explicit [12]. Therefore, this study addresses this research gap by (1) identifying relevant literature that elaborates the characteristics of societal responsibility in research processes. On the basis of this literature review, this study (2) develops an integrative framework based on criteria that enable scientists to systematically reflect and assess societally responsible research processes. We also discuss the framework's potential to trigger scientific discussion and a transformative turn in research processes supporting sustainable development.

This work is also motivated by a request of three German non-university research organizations, the Fraunhofer Gesellschaft, the Helmholtz Association and the Leibniz Association, which combined represent approximately 80,000 staff members, to develop a framework for socially responsible research processes [31]. The purpose of this framework is to awaken and enhance awareness and self-reflection among researchers and research managers about the impacts of research processes on societal development. The framework aims to (a) be integrative (i.e., merges criteria from scientific discussions on socially responsible research processes from all research fields and disciplines) and (b) support the evaluation and assessment of research processes in these research organizations on a gradient from basic to applied research projects. The three research organizations are currently discussing the framework and a roadmap for implementation is under development.

Methodological approach

We searched the ISI Web of Science database to identify peer-reviewed relevant literature from 2005 to 2015 that discussed the characteristics of socially responsible research processes (Figure 1). This database was selected to

Figure 1



Chronological order of publication years of relevant studies and core studies.

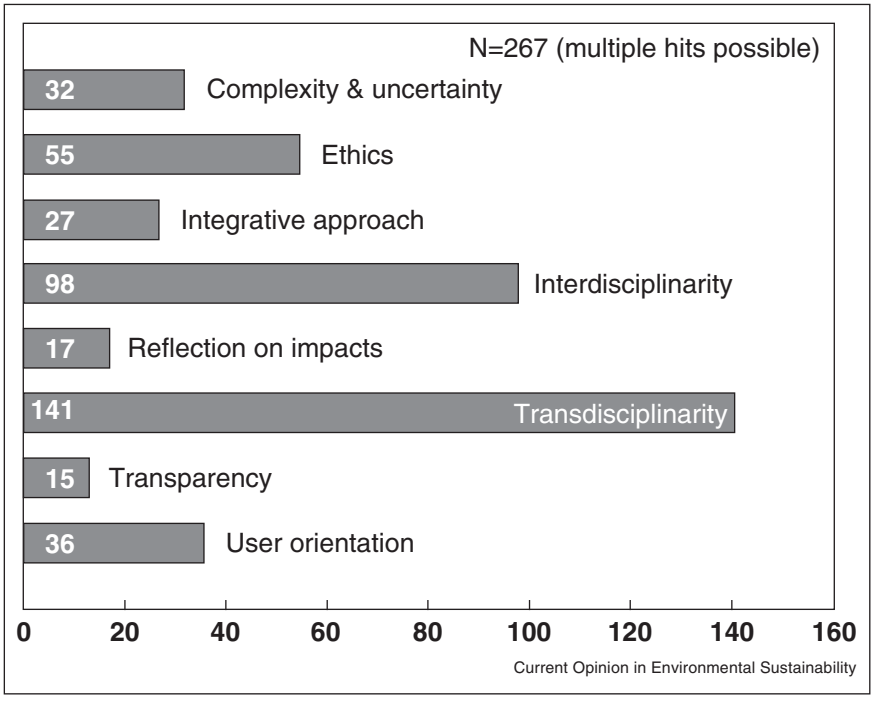
exploit wide-ranging scientific indices from the core collection encompassing the Science Citation Index, Social Sciences Citation Index and Arts & Humanities Citation Index, thereby exploring how issues of societal responsibility and sustainability entered the classic sciences. The search was based on two search strings using several terms with variations of 'responsible' and 'sustainable'. Both terms represent the two progressive research fields currently discussing questions of the responsibility of science toward society as introduced above: sustainability science and RRI. The search terms are also sufficiently broad to identify studies from other disciplines that address societal responsibility in research processes. From 1506 search hits, 267 relevant studies were selected and analyzed (see supplementary information for the primary data, the detailed search and evaluation strategy and a discussion of its methodological limitations).

By reading each of the relevant studies, we explored criteria of societal responsibility in an iterative process. The iteration was necessary to track variations of meaning within one criterion of socially responsible research processes and define the key characteristics of a criterion. After the identification of the characteristics and their condensation into particular criteria, we summarized the most frequent criteria (at least 10 studies discussing particular characteristics of one criterion) in a consolidated set of eight criteria (Figure 2). Thus, the identified characteristics of the eight criteria and their linkages and trade-offs (Table 1) are based on the evaluation of the relevant studies. The identified criteria per individual study are listed in Table S2 (supplementary information). A number of relevant studies elaborated on more than one criterion of socially responsible research. Pairs of commonly mentioned criteria in a single study were evaluated to discover overlap between criteria (Figure 3). Although the number of search hits is reproducible based on our literature review protocol in the supplementary information, our qualitative approach to identify the set of eight criteria in the relevant studies is influenced by our own interpretation and experiences and might yield different results when applied by other researchers. The criteria are similar to a set of hypotheses that require evaluation with further research. Therefore, our suggested set of eight criteria, embedded in a larger assessment framework that includes users, application levels and research stages, is open for discussion and adaptation based on further scientific analysis.

Eight criteria for socially responsible research

A discussion of the socially responsible conduct of research emerged in the mid-2000s and intensified from 2010 on, as evidenced by the increasing number of relevant studies identified from the literature review: four in 2005, 24 in 2010 and 70 in 2015, with a total of 267 relevant studies (Figure 1). In particular, 20 identified core studies published between 2010 and 2015 reflected solely on research processes and research characteristics that exhibit social responsibility and sustainable development, indicating a trend and forming a novel subject of

Figure 2



Number of relevant studies per criterion ($N = 267$).

Table 1

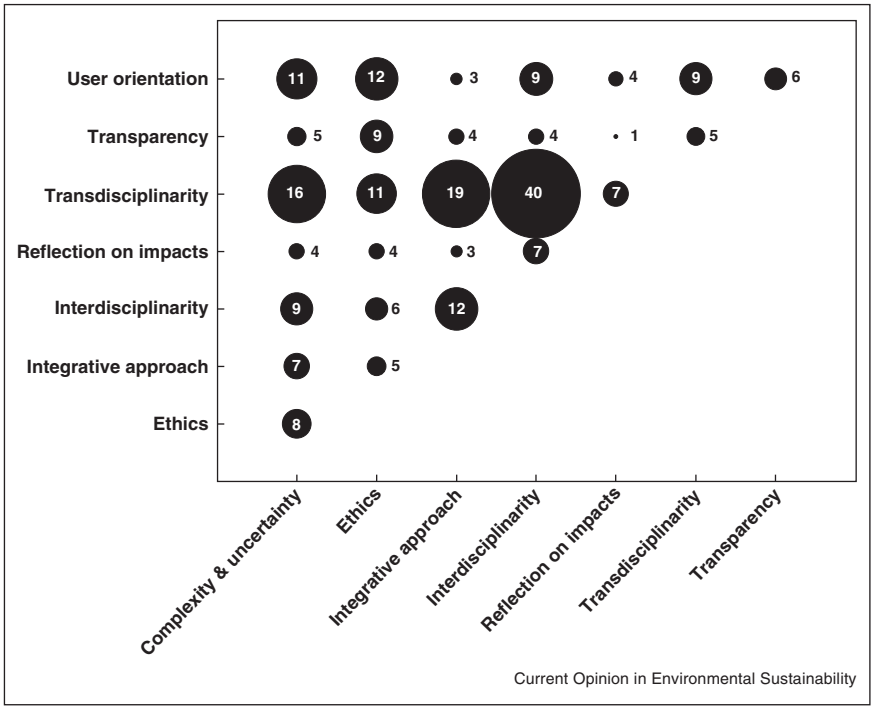
Set of eight criteria framing socially responsible research

Criteria		
Characterization	Key linkages to other criteria	Trade-offs and challenges
Approach to complexity and uncertainty		
Various dynamic and complex interconnections among natural, technical, and social systems increase complexity and uncertainty in any form of inference; this requires reflection on how scientists tackle emerging risks and the corresponding societal consequences	• Expanding set of interdisciplinary and transdisciplinary methods can help to improve the holistic examination of uncertainty and complexity • Transparent information and involvement of stakeholders during the research process can mitigate uncertainties and risks and is a morally responsible action • An integrative approach allows scientists to increase their capacity to iteratively include reflection and revision of complexity and uncertainty in research processes	• Dominance of and priority for short-term, linear and single-cause and single-sector explanations in science and society • Handling of opposing system components including social-environmental dilemmas • Insufficient set of methods to assess complex interactions • Dichotomy between the reduction of complexity and completeness
Selected literature from the review: Gall *et al.* 2015, Arentshorst *et al.* 2015, Brown 2013, Lindenfeld *et al.* 2014, Mauser *et al.* 2013, Owen *et al.* 2012		
Ethics		
Ethical, moral and value related questions affecting the society induced by research results, research funding sources, methodological designs and the determination of the value of science itself	• Ethical reflection on research impacts, for example, on various options, risks • Transparent reflection on risks and research uncertainties is an ethical matter • Interdisciplinary and transdisciplinary approaches and user dialogue are required to identify adequate ethical codes for evaluation that might change over time • Ethical values are complex because they differ over time, scales, and human groups	• Epistemically solid research can be socially reprehensible (e.g., racist trend) • Conflicts between 'free' and 'value-free,' the ideals of research versus the moral responsibility to support societal goals • Priority of evidence over values — can scientific evidence be 'value-free' at all? • Different interpretations of ethical matters make individual and collective decision making difficult (e.g., dual-use)
Selected literature from the review: Gergen *et al.* 2015, Bird 2010, Brey 2012, Brown 2013, Cornell *et al.* 2013, Scheirer and Dearing 2011, Stahl 2013		
Integrative approach		
Increasingly complex, multidimensional and diverse processes of modern societal development require consideration of all the relevant elements and interrelations to address research questions, thereby integrating different dimensions (e.g., themes, time, space, and knowledge systems)	• Integration of transdisciplinary and interdisciplinary knowledge and methods to provide suitable science-based orientation for decision makers in complex and dynamic societies • Integration of users and societal values to produce solution-oriented action knowledge for societal challenges • Balancing conflicting societal goals and values requires impact assessment of different options	• Balancing conflicting societal goals and the values of complex, diverse societies • Dichotomy between the reduction of complexity and completeness • Exchange and integration of assumptions and methodologies developed under different national/regional contexts • Identification of all relevant elements • Safeguard methodological standards
Selected literature from the review: Luederitz *et al.* 2015, van Kerkhoff 2014, Jerneck *et al.* 2011, Mauser *et al.* 2013, Spangenberg 2011		
Interdisciplinarity		
Integration of mindsets and methods from different scientific disciplines and cooperation across their borders to develop new methodological approaches and research results that would be inconceivable from a single disciplinary perspective	• Supports integrative research approaches to solve complex societal problems • Unlike transdisciplinarity, interdisciplinarity remains strictly within the realm of scientific logic and standards of knowledge production without incorporating non-scientific knowledge	• Differences in ontology and epistemology across disciplines — develop a common language and new methods • Multi-disciplinarity or parallel disciplinary processing instead of integration • Integration versus autonomy of disciplinary research — organizing co-existence while maintaining diversity • Alienation between the respective disciplines
Selected literature from the review: Polk 2015, König 2015, Brandt *et al.* 2013, Baumgärtner *et al.* 2008, Botey *et al.* 2012, Jerneck *et al.* 2011, Kastenhofer *et al.* 2011		

Table 1 (*Continued*)

Criteria		
Characterization	Key linkages to other criteria	Trade-offs and challenges
Reflection on impacts		
Assessment of the benefits and risks of research outcomes and innovation (e.g., intended/unintended, positive/negative, ex-ante/post) for the society and for sustainable development, using, for example, participatory methods and forecasting	• Identify the 'right' impacts and how they can be achieved in an ethically acceptable, safe and sustainable manner • Transparent participation of stakeholders and communication to decision makers • Impact assessment requires an integrative approach (interdisciplinary and transdisciplinary) • High uncertainties require comparative assessments of different options	• What are the 'right' impacts? (political/societal negotiation) • Identification of context/system border and analytical focus of assessment • Handling of societal conflicts of interests and communication strategies
Selected literature from the review: Arentshorst *et al.* 2015, Gall *et al.* 2015, Eden *et al.* 2013, Miller and Neff 2013, Pintér *et al.* 2012, Wiek *et al.* 2013		
Transdisciplinarity		
Integration of real-world knowledge via engaging non-scientific actors in specific scientific discourses and research questions, inclusion of participatory methods, and dissemination of scientific insights into societal discussions	• Supports integrative research approaches and creates new knowledge for solving complex societal problems • Strengthens the legitimacy and relevance of research, for example, in assessment of progress toward sustainability • Transparent and cooperative conduct of research and dissemination of results • Unlike user orientation, transdisciplinarity stresses the interactive participatory process of co-design and co-production of knowledge (two-directional)	• Identifying and integrating relevant actors and bodies of knowledge (in a manner as transparent and balanced as possible) • Development of a common language, set of methods, and mutually reliable dialogue Alienation between the respective discipline
Selected literature from the review: König 2015, Brandt *et al.* 2013, Jerneck *et al.* 2011, Mauser *et al.* 2013, Schaltegger *et al.* 2013, Spangenberg 2011, Talwar 2011		
Transparency		
Clear and user-oriented communication about funding, legitimation, research design, methods and their limits and impacts on research results and society ex ante, during, and ex post at all stages of the research process	• Transparency resembles closely the reflection of ethical issues and reliable scientific scrutiny of research by opening up to the public and to other scientists • Inform user groups about the risks and benefits of research results and alternative actions in complex and uncertain societal contexts, thereby increasing the legitimacy and public acceptability of decisions • Supports exchange of information in interdisciplinary and transdisciplinary research processes	• Gatekeepers of information limit access to reliable information (knowledge not evenly distributed) • Competitive disadvantages because of transparency in research processes (e.g., proposals for funding, publications) • Handling of societal and scientific conflicts related to transparent research processes • Overflow of information
Selected literature from the review: Gergen *et al.* 2015, Krabbenborg and Mulder 2015, Pintér *et al.* 2012, Wiek *et al.* 2012, Scheirer and Dearing 2011,		
User orientation		
Inclusion of all the relevant users of research results to enhance the integration and usability of results in science and society; target-group-oriented knowledge sharing	• Discussion of inevitable and unintended societal impacts of research results, for example, dual use problems from an ethical viewpoint • Supports connectivity of research results within an integrative approach • Transparent dialogue can enhance the generation and implementation of new knowledge • Unlike transdisciplinarity, user orientation is characterized by communication with affected citizens and stakeholders and supports decision making (one-directional)	• Conflict between focus on quality of work versus reflection about societal consequences and usability • Identifying relevant user groups and communication channels at different stages of the research process (in a manner as transparent and balanced as possible) • Handling of controversies among different user groups
Selected literature from the review: Bird 2010, Bond and Morrison-Saunders 2011, Matso and Becker 2014, Owen *et al.* 2012, Stahl 2013, Talwar *et al.* 2011		

Figure 3



Overlaps between criteria (240 pairs of commonly mentioned criteria per individual study, note: different numbers of studies per criteria, cp. Figure 1, influence the highest possible number of overlaps between two criteria).

discussion on the question of how researchers should reflect on and enhance their scientific conduct and research processes [12,30••,32••,33•,34••,35–37,38•,39,40,41••,42,43••,44•,45••,46•,47•,48•,49••]. A detailed evaluation of the core studies is shown in the supplementary information (Table S3). Taken together, the relevant and included core studies outline a variety of scientific approaches that contribute to socially responsible research and frequently stress the need for such research processes to create sustainable societal development.

We identified eight corresponding criteria from the relevant and core studies that help assess research processes from the perspective of societal responsibility: (1) approach to complexity and uncertainty, (2) ethics, (3) interdisciplinarity, (4) integrative approach, (5) reflection on impacts, (6) transdisciplinarity, (7) transparency and (8) user orientation. All eight criteria are important for an interlinked assessment. Therefore, they are not listed in order of priority but in alphabetical order. Their characteristics, linkages, boundaries and challenges to their application are described in detail in Table 1. The number of times each criterion is mentioned varies among the relevant studies, but the criteria 'interdisciplinarity', 'transdisciplinarity' and 'ethics' clearly represent the majority (Figure 2, Table S2). This distribution is not surprising because many of the identified relevant studies can be assigned to sustainability sciences and 'interdisciplinarity' and 'transdisciplinarity' are two established approaches to address and include societal concerns in research processes in this research field. In addition, a number of the relevant studies from clinical and technology innovation research intensively discuss ethical accountability in research processes.

Most of the individual criteria are central issues of societal responsibility that are well established by communities of scholars in various disciplines, such as the 'reflection on impacts' in technology innovation research (for a detailed evaluation of the core studies see Table S3 in the supplementary information). Most contributions to the set of criteria come from sustainability science [examples from the core studies: 32–40] including studies from sustainability assessment [41••,42], complexity studies [43••] and ecosystem services research [44•]. Furthermore, relevant studies from the responsible research and innovation (RRI) initiative contributed to the set of criteria [examples from the core studies: 45, 46]. In addition, the framework incorporates relevant and core studies from other research fields, such as health studies and clinical research, technology engineering, disaster risk research, ecological economics, psychology and education and philosophy [examples from the core studies: 12, 30, 47–49]. Thus, the set of eight criteria is derived from a

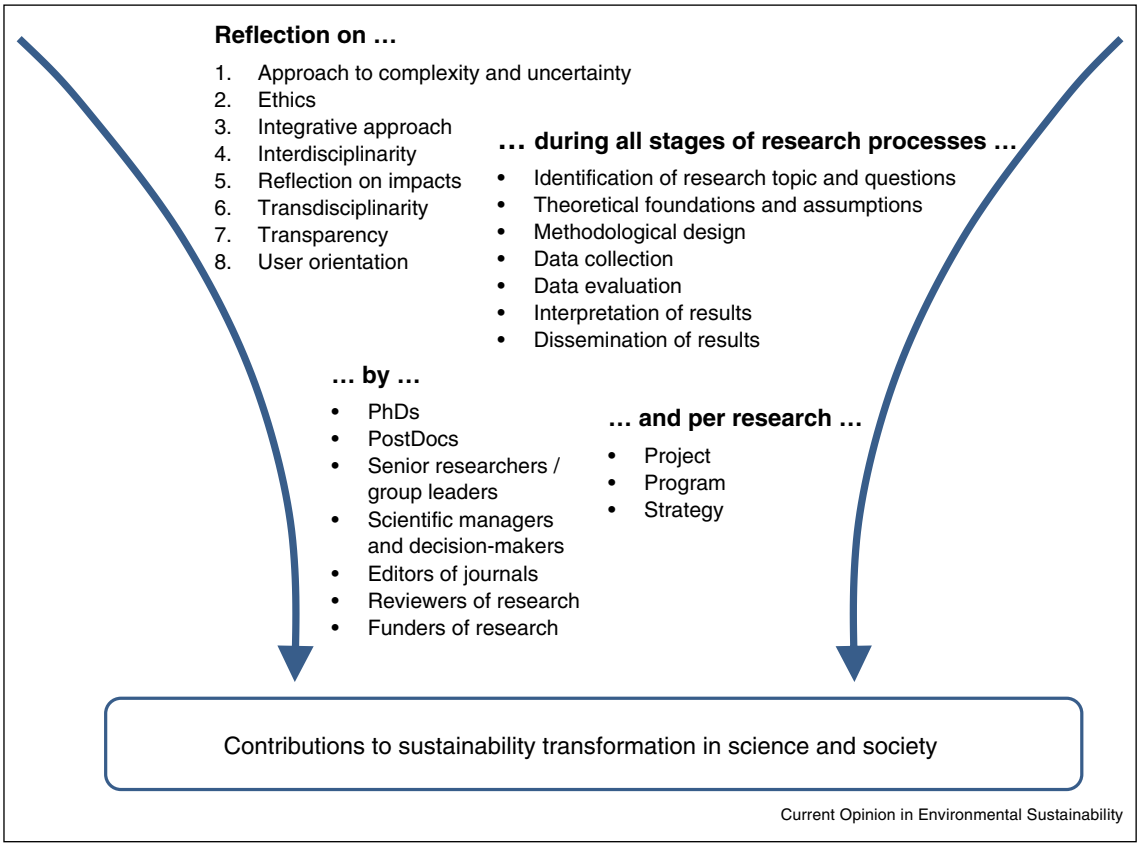
broad range of disciplines and fields of research that originally discussed characteristics of societal responsibility in research processes.

An evaluation of the overlap between the criteria mentioned in the 267 relevant studies (Figure 3) suggests clusters of criteria from our perspective. First, the many overlaps among the criteria 'transdisciplinarity', 'interdisciplinarity' and 'integrative approach' reflect how multiple dimensions of research challenges are addressed in complex, real-world situations, that is, researchers consider societal interests and the involvement of societal actors together with interdisciplinary methods in an integrative approach. Second, the 'ethics', 'transparency' and 'user orientation' criteria seem to commonly address fair communication processes between research and societal actors. Third, the examination of the characterization of the criteria (Table 1) revealed that a number of criteria emphasize the relevance of actors within the research process ('transdisciplinarity', 'interdisciplinarity', 'user orientation' or 'ethics'). Such potential clusters of criteria might facilitate assessment and application, such as from the specific perspective of actor involvement. However, the consolidation of such potential clusters of different criteria requires further analysis and a focus on strong relationships between particular criteria weakens the application of less established criteria. Therefore, we suggest at this point a joint application of all eight criteria that integrates knowledge from different disciplines and enables researchers to comprehensively reflect on the characteristics of a socially responsible research process (Table 1).

An integrated assessment framework for socially responsible research

This review article synthesizes the contributions from peer-reviewed scientific literature in a coherent framework for the integrative assessment of socially responsible research (Figure 4). Ideally, the identified set of criteria should be continually assessed during all stages of the research process as well as ex ante or ex post to enable adaptation within the research process. The criteria should be useful to scientists, scientific managers, journal editors and reviewers, research funders and decision makers at different career levels for individual research projects, larger research programs and research strategies. Thus, the integrative assessment framework includes a multi-dimensional and dynamic perspective on scientific actors and organizational structures. The identified eight criteria suggest initial points for assessing in detail how

Figure 4



Integrative assessment framework for socially responsible research processes supporting sustainability transformation.

socially responsible research is processed. On the basis of the eight criteria delineated in Table 1, assessments might start with questions such as the following:

- How is the way I conduct research related to societal development?
- Who should be included in research processes to fulfil societal requirements?
- For whom am I conducting my research and why?
- At what phase of my research process are different criteria of the framework relevant?
- What can I contribute to research processes to ensure that societal requirements are met?
- How does my position within the scientific system influence a reflection on socially responsible research processes?

The assessment should be based on scientists' and scientific managers' self-reflections about their research projects, programs or strategies at different organizational levels. Ideally, the assessment results should also be communicated to the appropriate scientific and societal communities. The relevance and level of rigor for particular criteria depend on the individual research question or design. Not all criteria may be applicable in all cases and some criteria may be less relevant than others. However, reflection on all criteria, their linkages and ambivalences is necessary to discover areas of non-awareness and previously unconsidered socially responsible issues. Additionally, individual or organizational reflection and judgement boundaries should be acknowledged. Finally, the development of detailed standards and checklists for reflection and assessment of the eight criteria, enhancing the initial list of reflection questions introduced above, is challenging because of the variety of research questions and methods across scientific disciplines. Here, application examples aid the development of the framework toward practicability.

Contributions of the framework to sustainability transformation

The application of the framework and its criteria as a central characterization of socially responsible research is one way to transform research processes and the scientific system toward sustainability transformation. Given the influence and impact of scientific results on societal development, the framework also has potential to support the transformation of unsustainable business models, life styles and politics, for example, via a transparent reflection on the disadvantages and advantages of particular technologies for the ethical standards of a society. However, such reflection processes require additional resources (see next section: challenges and trade-offs) that are not easily accessible at the current stage. Furthermore, reflection processes might not have sufficient outcomes that automatically lead to sustainable solutions. Thus, a development of a roadmap for the implementation of such reflection processes in current institutional environments in science and politics is crucial.

We also suggest that a joint reflection of the eight criteria within the framework (instead of an isolated review of specific criteria) would enhance the potential of socially responsible research processes to support sustainability transformation by discovering their linkages and stressing the complexity of societal responsibility. Specifically, a reflection on how to approach complexity and uncertainty in research processes would help address the risks emerging from unexpected events in complex and dynamic social and environmental systems [48•,50,51]. Expanding the reflection on ethical issues from one of internal scientific integrity to one that includes societal concerns [12,47•,49••] would support the desirable effects of research that lead toward sustainability transformation and, for example, sensitize scientists toward dual-use issues and societally doubtful effects. The integration of topics, knowledge and methods via different dimensions in research processes provides suitable science-based orientation and action knowledge for decision makers and stakeholders in complex and dynamic settings [37,43••,44•]. Thereby, the incorporation of interdisciplinary and transdisciplinary approaches enhances and joins the scientific and non-scientific knowledge bases for societal decision making [32••,33•,35,39,52]. Reflecting together with different actors on the impacts of research processes and results facilitates the identification of consequences with negative or positive effects on sustainability transformations [45••,48•,50,53]. Finally, transparent communication of the influence of theoretical assumptions, funding sources and its legitimation on the research process for all relevant users enhances the usefulness of research for scientific, social and environmental systems [40,41••,49••,54,55].

Challenges and trade-offs concerning the application of the assessment framework

Several trade-offs should be considered when reflecting on each of the eight criteria (see Table 1 for details) and when applying the whole framework to assess research processes from the perspective of social responsibility. For example, reflecting on the conduct of socially responsible research might limit the freedom of research [56,57]. Additionally, power relationships and path dependencies within the scientific system and at the policy-science interface as well as committee members influence decision making about research and may hinder the application of the framework for socially responsible research. This process may marginalize certain research topics in favor of others [35,45••,58]. It is challenging to raise awareness within the scientific system to create the conditions required for the application of criteria for socially responsible research processes and to develop corresponding competencies for sustainable transformation

in science, such as anticipatory, systemic thinking with normative, strategic and integrative elements [59].

Other challenges are issues of resource input and research competitiveness. These challenges include limited experience and knowledge, the specific requirements of particular research disciplines, topics or questions and other factors that influence the conduct of research. The application and assessment of the framework require training for researchers and scientific managers at all career levels, creating accountability for senior researchers and scientific managers, implementing corresponding evaluation standards in committees and funding programs and recognizing decisions involving career opportunities or by dissemination managers such as journal editors [60,61]. Thus, a successful process requires additional resources and human expertise [30••,62]. In particular, criteria that link knowledge generation to societal decision making ('user orientation' and 'transdisciplinarity') require greater financial resources, time, practice, meetings and inclusion of diverse user groups than research focusing solely on scientific knowledge generation [63–65]. Team-building measures among scientists and non-scientific actors for the assessment would enhance the application of the criteria and help balance the trade-offs between the traditions of scientific disciplines and research contributions toward sustainability transformation.

Conclusions and outlook: toward enhanced societal responsibility in research processes

This framework aims to contribute to a debate that might lead to further development of standards framing socially responsible research in support of sustainable development applicable to all fields and types of research. The joint and reciprocal assessment of the eight criteria identified in a broad base of literature exceeds established disciplinary frameworks for socially responsible research and therefore enhances the dissemination of new criteria to various research fields and disciplines. For example, a stronger reflection of ethical issues or societal impacts of research might benefit sustainability science that has a strong focus on transdisciplinary and interdisciplinary research. The identified core studies published from 2010 to 2015 promote such integrative mechanisms in research processes, often discussing several of the eight criteria simultaneously [12,30••,32••,33•,35,36,37,38•,39,40,41••,42,43••,44•,45••,46•,47•,48•,49••]. In addition, the framework aims to raise awareness about societal responsibility for less experienced scientists who are, for example, involved in basic research and are seldom directly involved in societal impacts of research. This study further makes clear that transacting a socially responsible research process is equally important for researchers as the intrinsic or extrinsic topical stimulus of research projects, strategies or programs for sustainability transformation. However, trade-offs with established principles, such as freedom of research or resource efficiency, make applying the framework challenging because the framework requires additional resources in a system that mainly follows principles of scientific excellence. Thus, pioneers of applications require specific support, particularly when the reflection of criteria for socially responsible research does not have a direct short-term effect on sustainable solutions.

The application of the framework should be based on a willing reflection by scientists but also requires a corresponding institutional framework within scientific organizations and funding organizations. Users of the framework require support by training measures, trained ombudsmen, a matching personnel strategy within the scientific system, including corresponding evaluation principles and integration in teaching, publishing and rewarding. Wide-ranging communication among all involved actors about the institutional framework is a prerequisite. Furthermore, we suggest examining both methodological deficiencies and the capability of scientists to assess criteria of socially responsible research. Additionally, it is crucial to systematically collect empirical evidence on applications of the framework across disciplines via accompanying research and developing materials as a means to guide scientists and scientific decision makers when applying the framework. Applications of the framework will increase awareness of societal responsibility in research processes and contribute to improved communication and cooperation between scientists and civil society to solve current and future societal problems and support sustainability transformation.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cosust.2016.09.004.

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- • of special interest
- •• of outstanding interest

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