



# Anticipating research impact for natural resource management: Impact-orientation in interdisciplinary contexts

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## ABSTRACT

Research faces increasing expectations to address societal challenges, such as climate change, biodiversity loss, and sustainable development. To better understand how and under which conditions research is most likely to meet these expectations, Research Impact Assessment (RIA) methods are required. While the contribution of transdisciplinary research processes to societal challenges is well researched, interdisciplinary research has received less attention. For agricultural and marine research, this study developed and pilot-tested an ex ante participatory RIA approach aimed at addressing the societal impact of interdisciplinary natural resource management (NRM) research. This RIA approach integrates established impact indicator sets and impact pathways to anticipate and plan for these impacts.

The approach applies three levels of impact: context-specific impacts, system-level impacts across sustainability dimensions, and transformational impacts on the Sustainable Development Goals (SDGs). By adopting impact indicator sets established for sustainability assessment studies (i.e. CICES, SAFA, SDG Global Indicator Framework), the approach provides a comprehensive, structured, comparative assessment of research impact potentials enabling improved contributions of research to environmental management objectives.

Across four heterogeneous case studies, the approach fostered a unified understanding among interdisciplinary teams, enabling them to systematically anticipate societal impacts, and supported the explication of impact pathways and key enablers and barriers. The use of established indicator sets broadened participants' perspectives beyond environmental impacts to include social, economic, and governance dimensions. Ex ante RIA built on externally legitimized criteria and indicators that translate across research contexts can thus strengthen interdisciplinary NRM research and make potential contributions to impacts comparable across cases.

## 1. Introduction

The growing need to address complex challenges, such as climate change, biodiversity loss, and sustainable development, has led to new interdisciplinary fields such as sustainability science (Bettencourt and Kaur, 2011). Interdisciplinarity can increase research impact (Okamura, 2019), and calls have been made for science “to move beyond classical disciplinary approaches and (...) consider interdisciplinary work that engages with practitioners to achieve sustainable transitions” (Brandt et al., 2013). Interdisciplinary research faces persistent cultural and institutional challenges, including high cognitive and collaborative demands and evaluation systems that favour

disciplinary work, often limiting productivity and academic recognition (Fontana et al., 2022; Graybill et al., 2006; Jacobs and Frickel, 2009; Leahey et al., 2017), with a persistent gap between ideal and actual interdisciplinary practice (Thierfelder et al., 2026).

Research is increasingly expected to deliver societal impact (Daedlow et al., 2016; Owen et al., 2012), reflected in policy frameworks such as RRI (Daedlow et al., 2016) and mission-oriented research (Mazzucato, 2018). The Horizon Europe Missions exemplify this policy shift, directing research toward contributing to solutions to pressing societal issues (European Commission, 2021). Research Impact Assessment (RIA) provides a structured approach to assessing, and planning for these contributions.

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Interdisciplinary natural resource management (NRM) research teams may particularly benefit from applying RIA by (1) jointly and structurally navigating diverse methods, epistemologies, and societal expectations, and (2) making the added value of interdisciplinary approaches visible through impact-orientation and evidence. This can be supported by institutionalizing societal impact through a culture of impact—e.g. by embedding it in strategic plans and formalizing RIA practices (Blundo-Canto et al., 2019; Ferré et al., 2025). These institutional efforts, alongside individual approaches such as this study, foster impact literacy (Bayley and Phipps, 2019).

While RIA traditions are well established in fields such as health sciences and research for development (Cameron et al., 2015; Pfeifer and Helming, 2024; Razmgir et al., 2021), they remain limited for NRM research (Kny et al., 2023; Plummer et al., 2022). Where approaches exist, they tend to focus on research processes and their proximate effects rather than on the wider changes in social-ecological systems that NRM research ultimately seeks to contribute to, and they rarely draw on criteria that are both societally legitimized and transferable across research contexts. Ex ante applications, which would allow such contributions to be anticipated and planned for while the research design is adaptable, remain limited in the NRM context (Pfeifer and Helming, 2024; Weißhuhn et al., 2018). Section 2 reviews these approaches in detail.

Building on these gaps, this study developed and applied a RIA approach in case studies across interdisciplinary NRM contexts, focusing on wider societal impact categories, and potential synergies and trade-offs. Using established, comprehensive, and context-adaptable criteria and indicators in an ex ante approach, the study examines (1) how interdisciplinary research contributes to societal impacts, (2) how these contributions can be anticipated, and (3) how the impact pathways leading to these complex impacts can be explicated. Further, we assess whether interdisciplinary NRM teams benefited from impact-orientation and how indicator sets support ex ante impact assessment.

The remainder of the paper is organized as follows: Section 2 presents the state of the art of RIA approaches and indicator frameworks relevant for NRM research, Section 3 the developed RIA approach for interdisciplinary NRM research, Section 4 its case study application, Section 5 the results, and Section 6 the discussion and conclusions.

## 2. Current approaches to assessing research impact for NRM research

To inform the development of our RIA approach, we analysed 19 RIA and innovation assessment approaches, hereafter *assessment approaches*, together with four additional indicator frameworks relevant to NRM research (Table 1). We refer to all 23 entries collectively as the *reviewed frameworks*. Most were drawn from the review corpus for mission-oriented RIA compiled by Pfeifer and Helming (2024) and supplemented with approaches from wider sustainability and transdisciplinary research contexts as well as with indicator frameworks relevant for research impact. The reviewed literature informed the design of the approach in two respects: it provided conceptual guidance and instruments, notably on the construction of impact pathways (see ASIRPA (Joly et al., 2015; Matt et al., 2023), ImpresS (Blundo-Canto et al., 2020; Faure et al., 2020), three-part-impact mapping (Fryirs et al., 2019) and PIPA (Alvarez et al., 2010)), on assessing SDG impacts (Eriksson et al., 2020), and on processes, enablers and barriers relevant to impact (Maag et al., 2018; Walsh et al., 2019); and it revealed gaps in the impact categories addressed, in the alignment with societal missions, and in the timing of assessment.

### 2.1. Which impact pathway stages are assessed?

As many societal impacts unfold over long and uncertain time horizons, RIA must be designed to accommodate delayed, indirect, or cumulative impacts of research. To reflect these multifaceted research

impacts contemporary RIA approaches have centred on logical frameworks (Douthwaite et al., 2003), adopting impact pathways that link inputs, research activities and outputs to outcomes and their anticipated societal impacts (Fig. 2). These pathways can explicitly recognize internal elements of the research project (such as resources, activities, and outputs) as well as external factors (including actors and contexts) whose interactions shape the emergence of impact.

CSIRO (2020) defines outcomes as the short-to-medium term changes expected from the successful delivery of research outputs—the uptake of scientific knowledge in policy, practice and public—and impact as change or benefit to the economy, environment or society beyond contributions to academic knowledge. The reviewed frameworks diverge from this definition in ways that make comparison difficult. Some introduce additional orders of impact, distinguishing direct effects on actors interacting with the research from indirect, spillover, or scaled effects (Alvarez et al., 2010; Barret et al., 2018; Faure et al., 2020; Fryirs et al., 2019; Joly et al., 2015). Others already treat the uptake of research-based knowledge as impact (Brennan and Rondon-Sulbaran, 2019; Fryirs et al., 2019; Rau et al., 2018), while some introduce alternative terms (e.g., 1st, 2nd, 3rd level effects in Schäfer et al., 2021).

For clarity, and for the coding of Table 1, we apply the following definitions:

- Input – resources flowing into research activities, including funding, expertise, data, and infrastructure.
- Research activities – the work planned and carried out within research.
- Outputs – what research activities produce, closest in proximity to the research context: peer-reviewed articles, reports, handbooks, tools, and applications.
- Outcomes – following CSIRO (2020), changes in behaviour, practice, or regulation among actors outside the assessed research activity but influenced by it: the dissemination and accessibility of knowledge, its uptake by practitioners, public bodies or civil society, and its application beyond the research activity itself.
- Processes – research-internal practices that aim to support research uptake, such as collaboration, engagement, and knowledge exchange.
- Impact – changes in the social-ecological system to which the research contributes.

The definition and use of the term 'impact' have been widely debated. Bornmann (2012) documents the absence of consensus across competing labels, while literature at the science–policy interface has shifted towards broader framings of 'success' to capture diverse and often intangible outcomes and to avoid over-claiming (Cooke et al., 2020; Karcher et al., 2021). We retain 'impact' for three reasons. First, it is well established in institutional and funding contexts and compatible with impact pathway logic. Second, formative RIA requires attention to potential negative effects and trade-offs, so that adverse impacts can be anticipated and mitigated; 'success' is less suited to this, as it directs attention to desirable effects. This follows Reed et al. (2021), who broaden the term rather than replacing it. Third, the term allows a clear differentiation between the uptake and application of knowledge (outcomes), the processes supporting it, and contributions to changes in a social-ecological system (impact). Alternative framings integrate these — e.g., 'societal effects' encompasses outcomes and impacts (Kny et al., 2023; Lux et al., 2019; Schäfer et al., 2021)—but we retain the sequential distinction to keep the assessed pathway stage explicit.

Coded against these definitions, the majority of the reviewed frameworks focus on assessing the processes leading to impact, including barriers and enablers affecting them and the role of particular actors, while only one third address impact in terms of social-ecological changes (Chams et al., 2020; Eriksson et al., 2020; Faure et al., 2020; Fryirs et al., 2019; Joly et al., 2015; Matt et al., 2023; Henzler et al., 2020). The coding applies a consistent definition for the purpose of

**Table 1**

RIA approaches and indicator frameworks relevant to natural resource management research. (Entries drawn from the review corpus of Pfeifer and Helming 2024 (N = 70) and supplemented with further relevant entries; all entries were re-coded for the present study; definitions of coding categories in Supplementary Material SMI; ● primary focus; ○ covered; – not covered; NA not applicable).

| Approach                                                                                  | Developed for    | Disciplinarity    | Assessed impact pathway stage |        |         |        | Timing  | Mission alignment | Origin of impact criteria |
|-------------------------------------------------------------------------------------------|------------------|-------------------|-------------------------------|--------|---------|--------|---------|-------------------|---------------------------|
|                                                                                           |                  |                   | Processes                     | Output | Outcome | Impact |         |                   |                           |
| <b>A. Natural resource management — terrestrial / agricultural (N = 6)</b>                |                  |                   |                               |        |         |        |         |                   |                           |
| ImpresS ex post (Faure et al., 2020)                                                      | CIRAD            | unspecified       | ●                             | ○      | ○       | ●      | ex post | explicit          | case-generated            |
| ImpresS ex ante (Blundo-Canto et al., 2020)                                               | CIRAD            | unspecified       | ●                             | ○      | ●       | ○      | ex ante | explicit          | case-generated            |
| ASIRPA ex post (Joly et al., 2015)                                                        | INRAE            | unspecified       | ●                             | ○      | ○       | ●      | ex post | implicit          | case-generated            |
| ASIRPA Real-Time (Matt et al., 2023)                                                      | INRAE            | unspecified       | ●                             | ○      | ○       | ●      | ex ante | implicit          | case-generated            |
| Participatory impact pathways analysis (Alvarez et al., 2010)                             | CGIAR            | unspecified       | ●                             | ○      | ●       | ○      | mixed   | implicit          | case-generated            |
| Societal impact assessment for a sustainable agri-food sector (Chams et al., 2020)        | general research | unspecified       | ●                             | ○      | ○       | ●      | ex post | implicit          | case-generated            |
| <b>B. Natural resource management — marine / aquatic (N = 4)</b>                          |                  |                   |                               |        |         |        |         |                   |                           |
| Three-part impact mapping (Fryirs et al., 2019)                                           | general research | unspecified       | ○                             | ○      | ●       | ●      | ex post | explicit          | external target system    |
| Knowledge utilisation model (Hoffmann et al., 2019)                                       | general research | transdisciplinary | ●                             | ○      | ●       | —      | ex post | implicit          | framework-internal        |
| Social learning in coastal management research (Smith et al., 2009)                       | general research | transdisciplinary | ●                             | ○      | ●       | —      | mixed   | implicit          | framework-internal        |
| Knowledge transfer processes (Krause and Schupp, 2019)                                    | AWI              | transdisciplinary | ●                             | ●      | ○       | ○      | mixed   | none              | framework-internal        |
| <b>C. Wider sustainability and transdisciplinary research (N = 9)</b>                     |                  |                   |                               |        |         |        |         |                   |                           |
| Impact of interdisciplinary sustainability research (Rau et al., 2018)                    | general research | interdisciplinary | ●                             | ●      | ●       | ○      | ex post | implicit          | framework-internal        |
| Assessment of transdisciplinary research characteristics (Belcher et al. 2019)            | general research | transdisciplinary | ●                             | ●      | ●       | ○      | ex post | implicit          | framework-internal        |
| Impact of transdisciplinary sustainability projects (Brennan and Rondon-Sulbaran, 2019)   | general research | transdisciplinary | ●                             | ●      | ●       | ○      | ex ante | explicit          | framework-internal        |
| Evaluation of transdisciplinary collaborations (van Drooge and Spaapen, 2017)             | general research | transdisciplinary | ●                             | ●      | ●       | ○      | ex ante | none              | case-generated            |
| Evaluation framework for actionable-knowledge production (Mach et al., 2020)              | general research | transdisciplinary | ●                             | ●      | ●       | —      | ex post | implicit          | case-generated            |
| Systematising societal effects of TD research (Schäfer et al., 2021)                      | general research | transdisciplinary | ●                             | ●      | ●       | ○      | mixed   | implicit          | framework-internal        |
| Evaluation method for societal effects of transdisciplinary research (Walter et al. 2007) | general research | transdisciplinary | ●                             | ●      | ●       | ○      | mixed   | none              | framework-internal        |
| SDG Impact Assessment Tool (Eriksson et al., 2020)                                        | innovations      | unspecified       | ○                             | ○      | ○       | ●      | mixed   | explicit          | external target system    |
| SDG-based innovation assessment (Henzler et al., 2020)                                    | innovations      | unspecified       | —                             | —      | —       | ●      | ex ante | explicit          | external target system    |
| <b>D. Further relevant indicator frameworks (N = 4)</b>                                   |                  |                   |                               |        |         |        |         |                   |                           |
| “Success” in applied environmental research (Cooke et al., 2020)                          | general research | unspecified       | ●                             | ●      | ○       | ○      | NA      | NA                | NA                        |
| Indicators for knowledge brokers (Maag et al., 2018)                                      | general research | unspecified       | ●                             | ●      | —       | —      | NA      | NA                | NA                        |
| Reference framework for scientific and socio-economic impact (OECD, 2019)                 | general research | unspecified       | ●                             | ●      | ●       | ○      | NA      | NA                | NA                        |
| Typology of barriers and enablers of evidence use (Walsh et al., 2019)                    | general research | unspecified       | ●                             | ○      | ●       | ○      | NA      | NA                | NA                        |
| <b>E. This study</b>                                                                      |                  |                   |                               |        |         |        |         |                   |                           |
| Ex ante RIA for interdisciplinary NRM research (this study)                               | ZALF / ZMT       | interdisciplinary | ●                             | ○      | ○       | ●      | ex ante | explicit          | external target system    |

comparison; it is not intended to dispute how individual approaches define their own effects.

## 2.2. When and for what kind of research is impact assessed?

The majority of the analysed assessment approaches assess impact ex post, after the research activity has concluded. Several imply mixed assessment timings but remain dominated by ex post evaluation, with ex ante application considered only in general terms. This confirms the underrepresentation of ex ante assessment for NRM research fields (Pfeifer and Helming, 2024; Weißhuhn et al., 2018). ImpresS ex ante (Blundo-Canto et al., 2020) and ASIRPA<sup>Real-Time</sup> (Matt et al., 2023), illustrate how early RIA application enables researchers to establish societal goals, anticipate potential impacts and the mechanisms contributing to them, and account for different time horizons over which impacts may emerge (Chams et al., 2020; Faure et al., 2020; ILRI, 2020; Weißhuhn et al., 2018). Hence, timing conditions how far along the impact pathway an assessment can reach: changes in a social-ecological system rarely materialize within a project's lifetime, so they can be anticipated ex ante but are seldom observable ex post within the assessed period (Pfeifer and Helming, 2024).

Of the 19 assessment approaches analysed, only one approach specifies the application for interdisciplinary research projects (Rau et al., 2018). Half do not specify the disciplinary orientation of their application, while the other half makes its application for transdisciplinary research explicit. We recognize notable advancements of RIA approaches in transdisciplinary research (e.g., Belcher et al., 2019; Schäfer et al., 2021; van Drooge and Spaapen, 2017; Walter et al., 2007). However, their strong focus on co-creation with stakeholders often leaves the interdisciplinary dimension underexplored, with attention remaining on impact-generating processes and outcome categories in proximity to the research project rather than on wider societal impact categories. This is not a limitation of those approaches so much as a consequence of what they were designed to assess.

Of the approaches covering aquatic and marine contexts (Hoffmann et al., 2019; Krause and Schupp, 2019; Smith et al., 2009), none extends beyond the conditions and processes leading to impact; only impact mapping in a fluvial context reaches the assessment of impact dimensions themselves (Fryirs et al., 2019). In terrestrial and agricultural contexts, by contrast, the structured reflection of different impact dimensions has become considerably more established (Pfeifer and Helming, 2024).

A further limitation is that RIA approaches in the NRM context are predominantly guided by research fields—such as agricultural research see ASIRPA (Joly et al., 2015; Matt et al., 2023) and ImpresS (Blundo-Canto et al., 2020; Faure et al., 2020)—rather than categories of impact (Chams et al., 2020). Therefore, their criteria are difficult to transfer between research contexts, and impacts outside the thematic focus of the respective field risk remaining unaddressed. Approaches developed for sustainability-focused research (Table 1, Group E) are designed to bridge research contexts but rarely extend beyond the outcome stage. The SDG-based framework of Eriksson et al. (2020), although developed for innovations rather than research, illustrates what an impact-driven assessment looks like when the categories are set by the target system rather than by the research field.

RIA approaches differ in how they link research activities to impact. For technical and applied innovations RIA may assess direct attribution, assuming research as a sufficient cause for specific and non-systemic impacts; for broader societal impacts or system-oriented research, it uses a contribution model, acknowledging research as a necessary but not sufficient factor and recognizing the collaborative and contextual factors that drive societal change (Reed et al., 2021). Across the reviewed approaches, this is consistently framed as contribution rather than attribution.

## 2.3. Where do impact criteria come from?

Approximately half of the reviewed assessment approaches apply case-generated criteria and indicators, developed anew for each application. These fit their context well but are difficult to transfer and compare across cases. The other half rely on framework-internal categories, which are transferable but not societally legitimatised. Only three entries draw impact criteria from established external target systems: the SDGs (Eriksson et al., 2020; Henzler et al., 2020) and the OECD (2019) impact of science categories (Fryirs et al., 2019). As both SDG-based frameworks were developed for assessing innovations rather than research, only one of the reviewed RIA approaches assesses research against an externally established target system. Further approaches (Blundo-Canto et al., 2020; Brennan and Rondon-Sulbaran, 2019; Faure et al., 2020) link their assessment to the SDGs as a mission without adopting them as impact categories, indicating that mission alignment is more often stated than operationalized in the criteria applied.

The lack of comprehensive criteria and indicators has been discussed in the RIA field for a long time (Bornmann, 2012; Joly et al., 2015) and remains unresolved, particularly for interdisciplinary NRM research. This leaves a gap in applying established comprehensive, context-adaptable set of impact criteria and indicators whose consistent use would support comparability across cases and facilitate alignment with streamlined monitoring and reporting processes.

## 3. The RIA approach for interdisciplinary NRM research

Based on the review in Section 2, the RIA approach presented here brings together five design elements. It is applied ex ante, at a point where research design remains open to adjustment (Section 3.1). It anticipates impacts against integrated criteria spanning three nested levels (Section 3.2). It applies a structured reflection on the enablers and barriers conditioning impact (Section 3.3). It is participatory, engaging research partners across disciplines and regions (Section 3.4). And it organises these elements within an impact pathway, making explicit how research activities are expected to contribute to societal impacts over time (Section 3.5).

### 3.1. Ex ante assessment

This approach aims to contribute to the still limited applications of ex ante RIA in NRM research (Pfeifer and Helming, 2024; Weißhuhn et al., 2018) to support early impact-orientation and impact planning. Constructing impact pathways ex ante makes explicit how research is expected to contribute to societal impacts over different time horizons.

### 3.2. Integrated impact categories and mission orientation

The review in Section 2 highlighted that few approaches offer impact criteria to assess changes to the social-ecological system and even fewer are linked to externally established target systems and missions. This study builds on evolving concepts of mission-oriented RIA (Blundo-Canto et al., 2020; Eriksson et al., 2020; Fryirs et al., 2019). By applying established target systems and indicators, the approach supports research activities to strategically align with broader societal missions to deliver meaningful impacts (Chapman et al., 2020).

Integrated RIA approaches, addressing multiple impact categories, can anticipate direct, indirect, positive, and negative impacts (Blundo-Canto et al., 2020; Commission, 2018; Walker et al., 2008) as well as synergies and trade-offs (FAO OED, 2020; Henzler et al., 2020). Hence, for this RIA approach, we sought criteria that are comprehensive enough to support the impact-orientation in various contexts of interdisciplinary NRM research. The approach employs a contribution model (Reed et al., 2021), mapping how diverse disciplinary inputs interact with other factors to influence change.

**Table 2**

Summary of applied impact dimensions (see Supplementary Indicator Set for full list of criteria and indicators; see Section SM2 for the full description of each level).

| Impact level                                                                                                                                                                                            | Impact dimensions                                                                                                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| <b>Context-specific impacts:</b> Assesses the research's influences on local ecosystem services and biodiversity within the project's immediate context. (CICES, 2018; World Resources Institute, 2014) | Biodiversity<br>Climate Change<br>Nutrient Management<br>Water<br>Biomass<br>Regulation of Risk<br>Cultural Value |
| <b>System-level impacts:</b> Evaluates broader effects across the four sustainability dimensions, highlighting trade-offs and synergies beyond the research setting. (FAO, 2013)                        | Environmental<br>Economic<br>Social<br>Governance                                                                 |
| <b>Transformational impacts:</b> Anticipates research contributions to long-term systemic change. (United Nations Statistical Commission, 2022)                                                         | 17 SDGs and respective sub-targets                                                                                |

Each unit of assessment (e.g., planned research project) is treated as a social-ecological system in which interactions between socio-economic and ecological dimensions are analysed and impacts anticipated. To support the anticipation of context-specific impacts (e.g., local impact on groundwater reserves) as well as broader system-level impacts (e.g., regional economic benefits) and contributions to transformation goals (e.g., SDG 8.4: global resource efficiency improved), we apply three impact levels, each with specific impact criteria and indicators. The levels are ordered by the scope of the system considered—from the immediate social-ecological context of the research, to the wider system in which it is embedded, to global sustainability goals—and by the degree to which anticipated impacts can plausibly be linked to the research activity itself. Criteria overlap across levels (e.g., context-specific impacts with environmental system-level impacts; system-level impacts with corresponding SDGs), so some changes are anticipated repeatedly, each level framing them from a different angle, while others are surfaced only at one level.

The three levels draw on established indicator sets (Table 2): ecosystem services criteria for context-specific impacts (CICES, 2018; World Resources Institute, 2014), SAFA sustainability indicators for system-level impacts (FAO, 2013), and the Global Indicator Framework for the SDGs for transformational impacts (United Nations Statistical Commission, 2022).

Established criteria and indicator sets enable a societally legitimized assessment of research impact potentials. Their comprehensiveness allows selective application of relevant indicators to reflect sector-specific contexts without compromising consistency of assessments (e.g., FAO, 2013; World Resources Institute, 2014). Recognized indicator sets also connect research and practice (Rasmussen et al., 2017), foster dialogue and co-learning, and remain compatible with other assessment frameworks such as environmental impact assessment and sustainability assessment.

This is particularly relevant where sector-specific criteria are unavailable. Sustainability assessment frameworks are well developed for terrestrial resource management (e.g., FAO, 2013; World Resources Institute, 2014). For marine and coastal contexts, no comparable framework is established; only the ecosystem services classification underlying the context-specific level (CICES, 2018) applies across both settings, as it is not developed for a particular resource system. The general formulation of the terrestrial sets allows their criteria to be generalized for marine applications, at the expense of specificity, making anticipated impacts comparable across resource systems.

### 3.3. Enablers and barriers to impact

Connecting impact-orientation to enablers and barriers and assessing impact relevant processes enhances our ability to understand the

**Table 3**

Summary of applied categories of enablers and barriers to impact (see SM3 for description of categories).

| Category of enablers and barriers | Definition and Sources                                                                                                                                                                                                                                                                                |
|-----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Relationships</b>              | The quality of relationships among project actors, essential for building trust and fostering collaborative environments (e.g., Cvitanovic et al., 2021; Rova, 2006; Walsh et al., 2019).                                                                                                             |
| <b>Capacities and attitudes</b>   | The skills, knowledge, attitudes and resources that enable actors to implement and promote impactful research practices and translate results into policy and practice (Maag et al., 2018; Walsh et al., 2019).                                                                                       |
| <b>Organizational structures</b>  | Institutional frameworks and support systems of actors that shape the effectiveness and reach of research efforts (e.g., Bayley and Phipps, 2019; Walsh et al., 2019).                                                                                                                                |
| <b>Contextual elements</b>        | External factors, such as organizational cultures, policies or societal priorities, that can either facilitate or impede actors in their achievement of desired impacts (Walsh et al., 2019).                                                                                                         |
| <b>Nature of evidence</b>         | The quality, relevance and accessibility of research results can be critical, enhancing transparency, credibility and the applicability of research outcomes (e.g., Cvitanovic et al., 2021; Mach et al., 2020; Newig et al., 2019).                                                                  |
| <b>Decision context</b>           | Decision-making and adaptive management processes, collaborative practices such as co-design, and the establishment of a shared vision are essential for aligning research with societal needs and maximizing impact potential (e.g., Mach et al., 2020; Norström et al., 2020; Temper et al., 2019). |
| <b>Other actors</b>               | Inclusion of diverse stakeholders, ensuring a comprehensive approach that integrates varied perspectives (e.g., Mach et al., 2020).                                                                                                                                                                   |

interactions and mechanisms that lead to impact (Blundo-Canto et al., 2020; Faure et al., 2020). The approach therefore includes a structured reflection on enablers and barriers alongside the anticipation of impacts.

The likelihood of achieving societal impacts through research is influenced by various factors of how research is conducted. While some factors are supported by quantitative evidence, such as transdisciplinary approaches and user engagement (Newig et al., 2019), the importance of others, such as building trust between researchers and policymakers (Cvitanovic et al., 2021), is primarily supported qualitatively. Unlike the detailed indicator lists available for assessing specific societal impacts (Section 3.2), social processes that take place during the research phase and support impact are challenging to compare, quantify, and capture due to their contextual nature (see examples of process indicators in Glaser et al., 2012).

To address this complexity in assessing the processes generating research impact, this study utilized criteria for societally responsible research (Ferretti et al., 2023) as well as further insights from Walsh et al. (2019) and the wider literature (Table 3). These elements were conceptualised as enablers when present and as barriers when absent or insufficient.

### 3.4. Participation

Involving diverse perspectives in research design enhances societal relevance and legitimacy of research (Belcher et al., 2016; Cash et al., 2002). This approach combines implicit and explicit stakeholder engagement to balance inclusivity with practical considerations (Faure et al., 2020). Implicit engagement draws on research partners' expertise to identify relevant actors, potential barriers and enablers, and how different stakeholders may influence or be impacted by the research—without requiring those stakeholders' direct participation at this stage (Reed et al., 2009). Explicit engagement involves all project partners across disciplines and regions in the RIA process, ensuring diverse perspectives are represented. This participation aims to embrace

**Table 4**

Summary case studies (BMBF/BMFTR = German Ministry for Research; GIZ = German Corporation for International Cooperation).

|                                         | Case Study 1                                                                                  | Case Study 2                                                                                                                                                 | Case Study 3                                                                                                           | Case Study 4                                                                                                                                                     |
|-----------------------------------------|-----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Name</b>                             | <i>Irrigation Technology Project</i>                                                          | <i>Marine NbS (Nature-based Solutions) Project</i>                                                                                                           | <i>Digital Agriculture Project</i>                                                                                     | <i>Blue Economy PA (Program Area)</i>                                                                                                                            |
| <b>Coordinating Institute</b>           | ZALF                                                                                          | ZMT                                                                                                                                                          | ZALF                                                                                                                   | ZMT                                                                                                                                                              |
| <b>Type</b>                             | Funded Research Project                                                                       | Funded Research Project                                                                                                                                      | Research Project before grant application                                                                              | Program Area                                                                                                                                                     |
| <b>Funding</b>                          | BMBF                                                                                          | GIZ                                                                                                                                                          | BMBF/BMFTR                                                                                                             | Various                                                                                                                                                          |
| <b>Duration</b>                         | 09.2022–02.2025                                                                               | 10.2022–10.2025                                                                                                                                              | 1st Phase 2019 - 2024<br>2nd Phase from 2025                                                                           | institutionalized                                                                                                                                                |
| <b>Focus Areas</b>                      | Interdisciplinary<br>Transdisciplinary<br>Global South (Central Asia)                         | Interdisciplinary<br>Transdisciplinary<br>Global South (East Africa)                                                                                         | Interdisciplinary<br>Global North (Germany)                                                                            | Includes:<br>Interdisciplinary<br>Transdisciplinary<br>Global South (South-east Asia, East Africa, Latin America)                                                |
| <b>Disciplines (selected in survey)</b> | Agriculture<br>Economics<br>Climate Science<br>Water Resources<br>Soil Sciences               | Anthropology<br>Aquatic Sciences<br>Arts & Humanities<br>Biodiversity & Conservation<br>Development Studies<br>Environmental Sciences & Ecology<br>Fisheries | Agriculture<br>Biodiversity & Conservation<br>Computer Sciences and Data Analytics<br>Environmental Sciences & Ecology | Oceanography<br>Economics<br>Computer Sciences and Data Analytics<br>Environmental Sciences & Ecology<br>Marine & Freshwater Biology<br>Modeling<br>Oceanography |
| <b>Total Number of Researchers</b>      | N = 5                                                                                         | N = 9                                                                                                                                                        | N = approx. 50                                                                                                         | N = approx. 30                                                                                                                                                   |
| <b>Participation Workshops</b>          | 12.2022–03.2023<br>N = 5<br>– WS 1: n = 5<br>– WS 2: n = 5<br>– WS 3: n = 5<br>– WS 4: n = 5  | 03.2023–06.2023<br>N = 9<br>– WS 1: n = 5<br>– WS 2: n = 7<br>– WS 3: n = 5<br>– WS 4: n = 4                                                                 | 05.2023–06.2023<br>N = 21<br>– WS 1: n = 12<br>– WS 2: n = 10<br>– WS 3: n = 5<br>– WS 4: n = 8                        | 05.2023–06.2023<br>N = 6<br>– WS 1: n = 5<br>– WS 2: n = 6<br>– WS 3: n = 5<br>– WS 4: n = 3                                                                     |
| <b>Participation Survey</b>             | 18.10.2024–11.11.2024<br>n = 5                                                                | 18.10.2024–11.11.2024<br>n = 2                                                                                                                               | 18.10.2024–11.11.2024<br>n = 2                                                                                         | 18.10.2024–11.11.2024<br>n = 2                                                                                                                                   |
| <b>Goals for RIA participation</b>      | – Understand societal impact concepts<br>– Familiarize with RIA methods<br>– Project planning | – Define shared vision<br>– Refine project setup                                                                                                             | – Define long-term vision<br>– Clarify researcher roles                                                                | – Align program goals with societal impact                                                                                                                       |
| <b>Utilization of RIA material</b>      | Retention for future research<br>Integration into project planning<br>Application in research | Uncertainty about usage                                                                                                                                      | Integration into project planning (included in second phase proposal > successful)<br>Application in research          | Integration into program planning                                                                                                                                |

the research's interdisciplinary character by ensuring that partner institutions contribute their unique expertise and perspectives. In interdisciplinary research settings, this provides a platform for constructive dialogue on differing views about science's societal role, supporting the mutual understanding (MacPherson et al., 2025) and coordinated planning toward shared goals that integration across disciplines requires (Haythornthwaite, 2006).

### 3.5. Impact pathway model

This RIA approach adopts a traditional linear impact pathway model to structure the progression from research inputs to societal impacts to provide a logical and visual framework, incorporating a Theory of Change perspective to articulate how specific impacts are expected to unfold over time (CSIRO, 2020). Although presented in a linear format to enhance clarity and visualization, the RIA approach acknowledges that interactions between elements are dynamic and non-linear.

## 4. Implementation of RIA approach in case studies

We iteratively applied, evaluated, and adapted the RIA approach in four multi-level case studies (see Table 4; see Section SM4 for detailed description), selected at two German research institutes, both conducting interdisciplinary NRM research: the Leibniz Centre for Agricultural Landscape Research (ZALF) on terrestrial resource management and Leibniz Centre for Tropical Marine Research (ZMT) on marine resource management. Authors' affiliations with these institutes ensured access to case study information and encouraged participation through

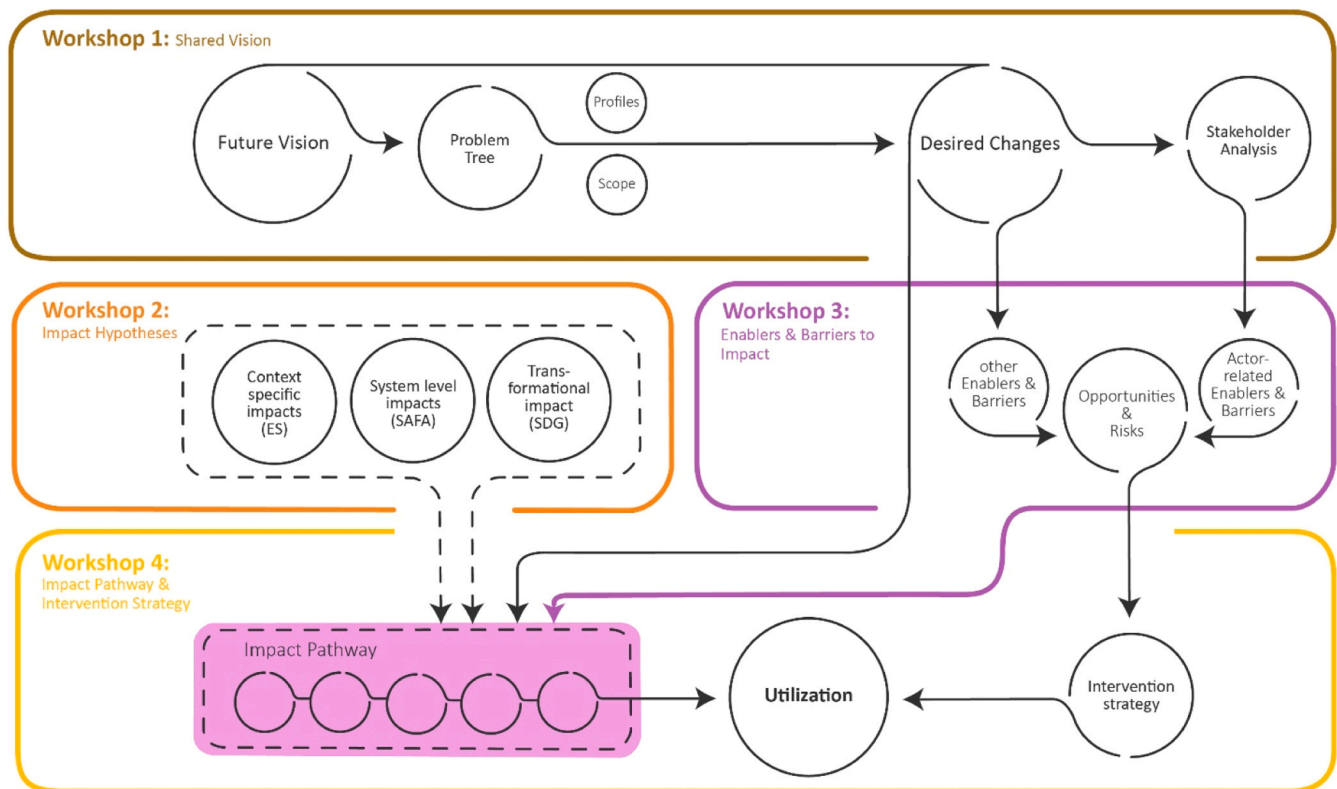
established personal connections.

The case studies were selected to span scales and stages of the research cycle: (i) one project before grant applications, (ii) two projects in early implementation after funding approval, and (iii) one institutional program area (thematic research area) in a strategic phase of redefining research goals. This multi-scalar application ensures that RIA supports both the granular planning of specific projects and the broader strategic alignment of research areas, making it a versatile tool for diverse assessment objectives (Blundo-Canto et al., 2020). To reflect the diversity of research contexts, selected projects were based in Germany as well as the Global South. Active participation from all project partners in the RIA was encouraged to ensure collaborative impact planning.

The *Irrigation Technology Project* sought to provide scientific support for the adoption of water- and energy-saving irrigation technologies in Uzbekistan. The *Marine NbS (Nature-based Solutions) Project* aimed to foster stakeholder networking to support the implementation of nature-based solutions and optimize ecosystem use with and for local communities in Madagascar and Zanzibar. The *Digital Agriculture Project* focused on using data-driven tools to harmonize biodiversity, resource use, and food production. The *Blue Economy PA* is a structural research area at ZMT addressing coastal resources and sustainable blue economy research, in which the approach was scaled up for programmatic planning at the institutional level, providing new insights into the approach's versatility.

### 4.1. Workshops

The RIA approach was applied in four consecutive, half-day



**Fig. 1.** Workshop overview (adapted from Ferse and Pfeifer, 2024); ES = indicators from ecosystem services assessment; SAFA = Sustainability Assessment of Food and Agriculture indicators; SDGs = Global Indicator Framework for the SDGs).

workshops, each addressing a component of impact planning (Fig. 1). Through guided exercises and collaborative discussions, researchers from the case studies (Table 4) constructed an impact pathway, each session building on previous outputs.

The first workshop introduced the approach and encouraged participants to articulate a “future vision” their research aimed to contribute, followed by a problem tree analysis (see Blundo-Canto et al., 2020), the derivation of desired changes, and a stakeholder mapping using the 3i’s framework by Reed (2019).

In the second workshop participants hypothesised dimensions and criteria of impact at three levels (Table 2), classifying them as direct or indirect, negative or positive, following Eriksson et al. (2020), and produced an initial draft of an impact pathway. In the third workshop participants identified enablers—factors supporting generation of these impacts—and barriers—factors potentially hindering it (Table 3).

The fourth workshop synthesized the impact pathway linking project inputs, activities, outputs and outcomes with anticipated impacts. These links were annotated to clarify their nature. Finally, participants developed an intervention plan (drawing on participatory impact pathways analysis and outcome mapping; see Alvarez et al., 2010) outlining actions, partnerships, and resources required. The co-created material was further elaborated through individual participant reflections and synthesized by the authors, who facilitated the RIA.

#### 4.2. Participant reflection of RIA and method application

An online survey was conducted after the workshops, involving workshop participants and other members of the assessed projects or program area. The survey yielded 11 complete responses, with 5 participants from the *Irrigation Technology Project* and 2 participants from each of the remaining case studies.

It focused on capturing personal assessments and varied perspectives of the identified research impacts. Survey participants rated the

intensity of the identified impact criteria from −3 (major negative impact) to +3 (major positive impact), informing the impact radars presented Section 5. Additionally, the survey gathered insights into participants’ prior experiences with interdisciplinarity and research impacts, their evaluations of the ex ante RIA method, and views on the future utility of workshop materials.

## 5. Results

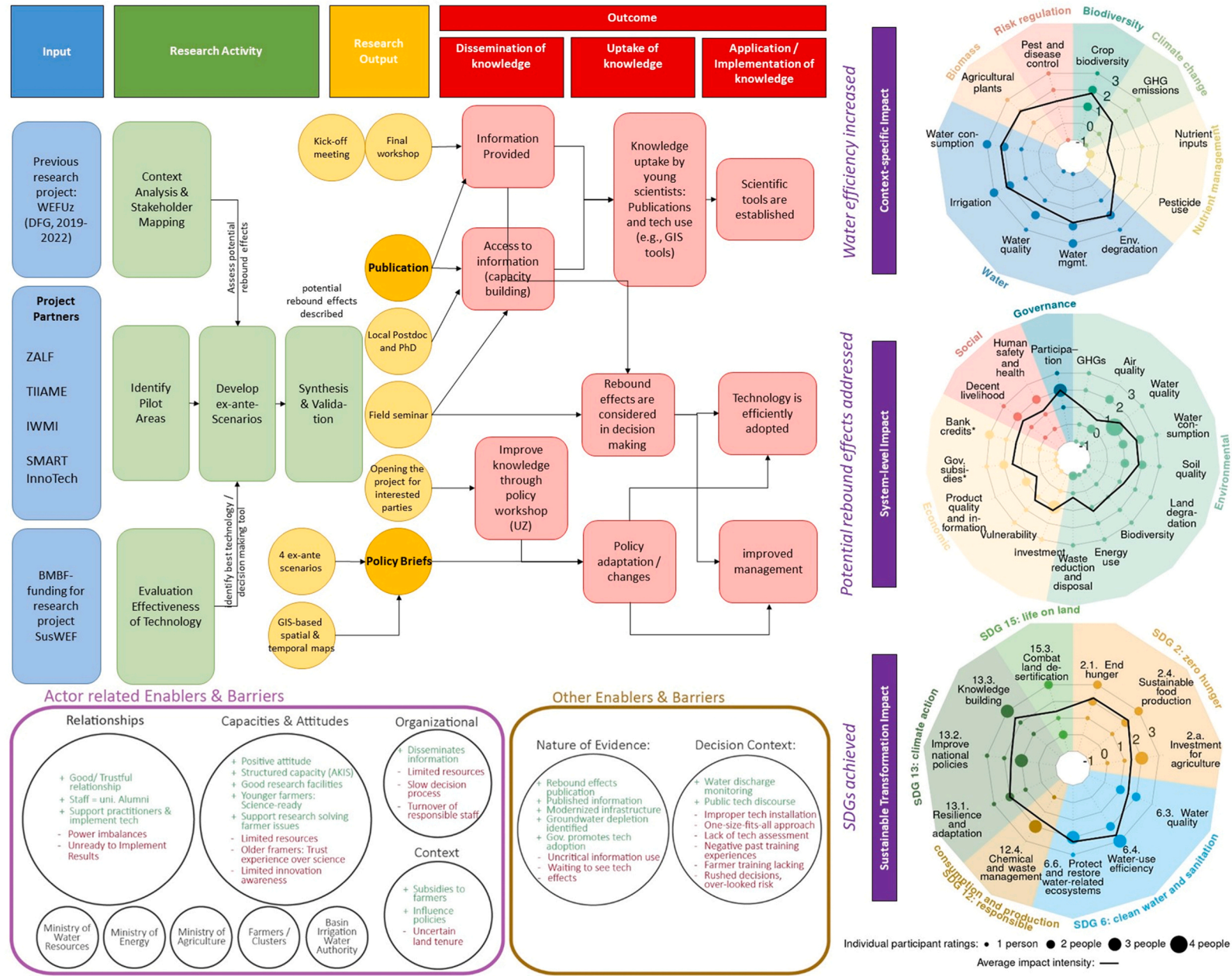
This study presents results from the application of the RIA approach across four case studies. The aim was twofold: (1) to anticipate impacts and reflect on enablers and barriers for each case and (2) to reflect on the RIA method itself.

Due to the participation by all project partners, the vision statement and impact pathway of the *Irrigation Technology Project* are presented first as an example. The subsequent sub-sections present anticipated impacts from the remaining three case studies, followed by a synthesis of general insights across all cases. Results on enablers and barriers to impact are presented across all four case studies.

#### 5.1. Exemplary vision statement and impact pathway for the *Irrigation Technology Project*

The *Irrigation Technology Project* formulated a vision centred on achieving food security by improving irrigation efficiency (Workshop 1; Section 4) by promoting appropriate technologies, developing local solutions for food, water, and energy challenges, and facilitating effective knowledge transfer. The vision from Workshop 1 informed the specification of inputs, activities, outputs and outcomes; impact hypotheses from Workshop 2 and enablers and barriers from Workshop 3 were synthesised in Workshop 4 into the pathway in Fig. 2:

INPUT—The *Irrigation Technology Project* built on prior research and combined funding, partnerships, and interdisciplinary expertise across



**Fig. 2.** Impact pathway Irrigation Technology Project (impact pathway following the Input-Activity-Output-Outcome-Impact logic; including impact radars for three impact levels (impact criteria rated from -3 (major negative impact - -2 and -3 were not selected and hence are not displayed) to +3 (major positive impact)); including identified enablers and barriers to achieving impact hypotheses).

several work packages.

**RESEARCH ACTIVITIES**—The diverse research activities included context analysis, stakeholder engagement, technology assessment, and scenario development to identify suitable irrigation solutions and assess potential rebound effects.

**OUTPUTS**—The project planned to deliver scientific outputs, policy-relevant materials, and capacity-building activities such as workshops and training.

**OUTCOME**—These outputs aimed to enhance knowledge dissemination and stakeholder accessibility. Knowledge uptake by young researchers was considered central in establishing scientific tools and methods. Additionally, policy workshops aimed to support informed decision-making and address potential rebound effects. Combined with policy adaptations, these activities were expected to drive the adoption of efficient technologies and improve management practices.

**IMPACT** – The *Irrigation Technology Project* aimed to translate research into tangible applications that foster sustainable development and improve water-use efficiency. The project anticipated significant impacts across several domains, which were validated in participants' reflections in Section 4.5 (see impact radars in Fig. 2):

- The project was expected to deliver three key context-specific impacts: improvements in water management, increased biomass production, and enhanced crop biodiversity. Additional impacts were anticipated for nutrient management, climate change mitigation, and pest and disease control, but because of the complexity and variability of these factors, these impacts were considered less certain.
- At the system-level, the project was expected to generate moderate to strong positive impacts, alongside potential synergies and trade-offs. Environmentally, it was expected to improve water-use efficiency and soil quality; economically, to stimulate private investment in sustainable practices through subsidies and bank credits; and in terms of governance, to enhance stakeholder participation and promote more inclusive and informed decision-making. Participants also identified trade-offs. Rebound effects from irrigation modernization could increase total water withdrawals and reduce downstream flows, heightening the risk of toxic dust storms from exposed sediments in the Aral Sea region. Expected improvements in soil conditions were considered potentially limited by reduced leaching and increased herbicide use, and higher electricity demand was expected to increase CO<sub>2</sub> emissions without a transition to renewable energy. A synergy was identified between fair access to means of production and the stability of agricultural production, suggesting that improved irrigation efficiency may strengthen equitable access to resources while enhancing economic stability.
- The project was anticipated to make moderate to strong positive contributions to several SDGs, aligning with global sustainability targets. For SDG 2: Zero Hunger, it was expected to support the goals of ending hunger (SDG 2.1) and promoting sustainable food production (SDG 2.4). For SDG 6: Clean Water and Sanitation, the project was expected to enhance water-use efficiency (SDG 6.4). It was further anticipated to contribute to SDG 13: Climate Action by enhancing education, awareness, and institutional capacity (SDG 13.3).

**ENABLER & BARRIERS** – Strong relationships with the Ministry of Water Resources were expected to facilitate dissemination of results, though limited funding and implementation capacity posed challenges. Positive relationships with the Ministry of Agriculture were considered beneficial but potentially constrained by slow decision-making processes and frequent staff turnover. Power imbalances with the Ministry of Energy and older farmers' reliance on experience were seen as limiting factors. Emerging younger farmers were identified as impact enablers, provided land tenure uncertainties were addressed. The Basin Irrigation Water Authority was perceived as potentially supportive of technology

implementation and policy influence, but was considered to lack innovation awareness. Favourable conditions were identified as including abundant scientific publications, modernized infrastructure, and governmental support for technology, tempered by uncritical information use, improper installations, and rushed, one-size-fits-all decisions. Areas for improvement included revising policies and informing irrigation practices by scientific data.

Relationships among key actors—including researchers, farmers, and policymakers—emerged as the most critical factor for achieving impact. Strengthening these relationships was expected to facilitate farmers' uptake of information, support demonstration sites, and promote subsidies for sustainable practices. Areas for improvement included enhancing trust through regular meetings with farmer co-operatives, ministerial staff, and stakeholders. Several further impact-generating processes emerged from the discussion.

## 5.2. Anticipated impacts across three impact levels

The following sections compare anticipated impacts at the three levels, identified in workshop 2 (Section 4) and assessed in the subsequent surveys, for the three other case studies *Marine NbS Project*, *Digital Agriculture Project* and *Blue Economy PA* (see Supplementary Indicator Set). General insights across all four cases are derived in each.

### 5.2.1. Contribution of the research to context-specific impacts

Anticipated direct and indirect impacts of NRM research on ecosystem services and biodiversity (Fig. 3) within the projects' immediate context were identified (CICES, 2018; World Resources Institute, 2014). Where necessary, agricultural criteria taken from World Resources Institute (2014) were generalized for marine context applications. The context-specific impacts for each case study are described in Fig. 3.

Overall, initial sorting and categorization of impacts occurred rapidly, but discussions on interpretations and interlinkages required significant time and deliberation. Many impacts were found to be context-dependent, with enabling conditions, such as supportive policies, critical for achieving positive impacts. Participants emphasized the importance of addressing political and social dimensions, which were subsequently explored in the broader discussion on system-level impacts (Section 5.2.2). The presented criteria and indicator set (see Supplementary Indicator Set) proved useful for the discussion and anticipation of context-specific impacts of NRM research. *Marine NbS Project* and *Blue Economy PA* each added one, and *Digital Agriculture Project* seven criteria beyond the presented criteria-set (marked with \* in impact radars in Fig. 2 and Fig. 3). Alternative indicator sets, like the FAO Agrobiodiversity Index, were suggested to offer further insights into under-explored impact dimensions.

### 5.2.2. Contribution of the research to system-level impacts

The examination of broader direct and indirect system-level impacts focused on environmental, economic, social, and governance criteria to highlight trade-offs and synergies beyond the research setting. While agricultural case studies benefited from established indicator sets, i.e. SAFA (FAO, 2013), marine research contexts lacked tailored indicators. Consequently, agricultural indicators were generalized for application in marine settings. Fig. 4 describes the anticipated system-level impacts, with a focus on non-environmental impacts (environmental impacts are presented in Section 5.2.1 and are not repeated here).

Social and economic aspects of the case studies often became apparent only after in-depth discussions, however emerging as critical factors. Participants highlighted their significance as the "currency" most relevant to policymakers addressing citizens' needs. Recognizing these dimensions is essential for ensuring research relevance in policy and decision-making. On this level, contextual and methodological differences within case studies led to heterogeneous perceptions of system-level impacts, yet the presented criteria and indicators set facilitated



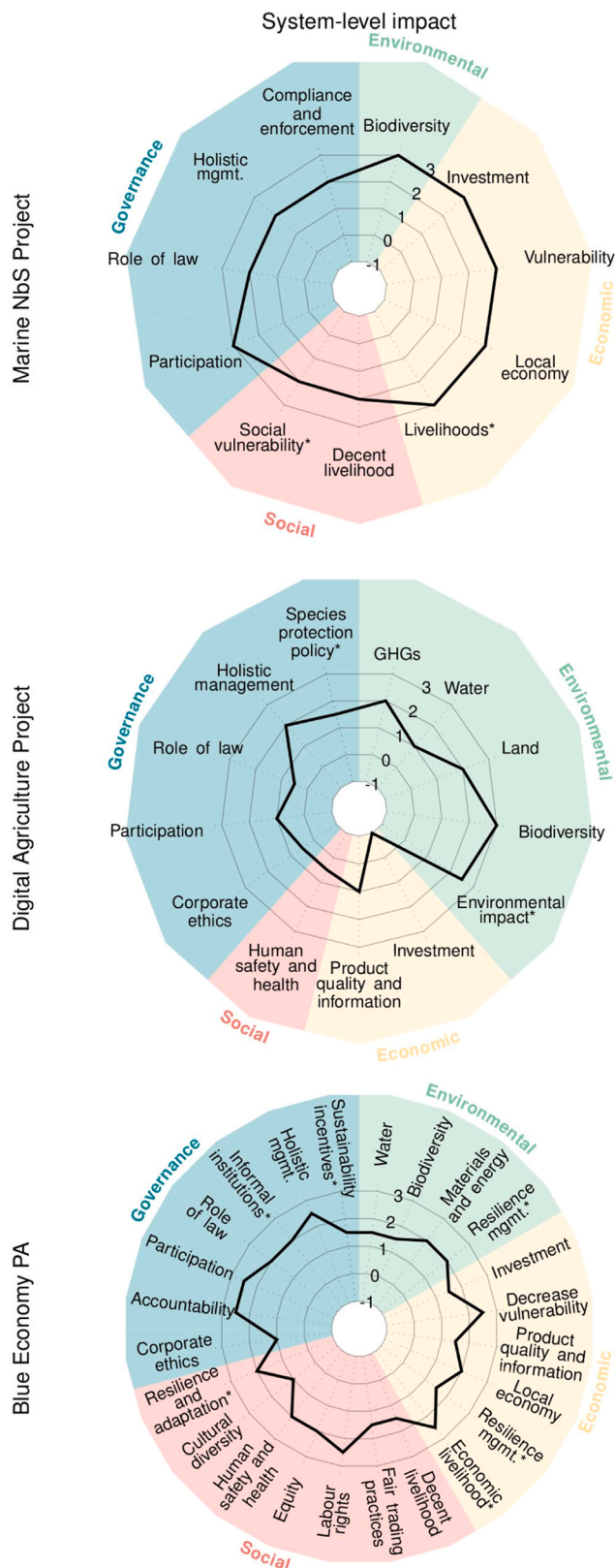


Fig. 4. Impact radars for system-level impacts (impact criteria rated from -3 (major negative impact) to +3 (major positive impact)).

sub-targets, our study applied a universal indicator set (United Nations Statistical Commission, 2022) applicable to both agricultural and marine research contexts. The sustainable transformation impacts of the case studies are described in Fig. 5, with a focus on their systemic contributions.

The Marine NbS Project anticipated **major positive economic impacts**, including increased investments, improved economic resilience, enhanced livelihoods, and increased payments of fees and taxes, particularly from tourism. **Governance impacts** were major for participation and moderate for rule of law (formal institutions), holistic management, and compliance and enforcement. For instance, incorporating local knowledge was seen as a way to improve compliance and foster acceptance. **Moderate social impacts** were identified, particularly in terms of decent livelihoods and reduced social vulnerability. Synergies were noted, where the inclusion of local communities improved power balances, positively affecting food and income security while enhancing economic livelihoods. These outcomes highlighted the interconnectedness of governance, social, and economic dimensions. No negative impacts were reported.

The Digital Agriculture Project anticipated **moderate governance impacts**, including holistic management and species protection policies, which were expected to support policymakers, primarily at the regional level, with positive environmental spillover effects. **Social and economic impacts were generally weak**. Weak positive impacts were anticipated for human safety and health (social dimension) and product quality and information (economic dimension). **Governance showed weak positive effects** in corporate ethics, participation, and rule of law (formal institutions). **Weak negative economic impacts** were reported for investments, as some measures were not deemed profitable. Appropriate policy interventions were identified as necessary to mitigate these challenges.

The Blue Economy PA anticipated major societal impacts across multiple dimensions. **Economic impacts** included enhanced resilience and improved economic livelihoods, while **social impacts** were major in the area of labor rights. **Governance impacts** were major, particularly in accountability, participation, and holistic management. Participation was discussed as a core impact, emphasizing co-creation and participatory research approaches. Improved participation was believed to have positive economic implications, enhancing food security and income stability, alongside social improvements in equity and labor rights. Low to moderate impacts were anticipated in various dimensions, including product quality and information (economic), fair trading practices, decent livelihoods and cultural diversity (social), and incentives for sustainability (governance). No negative impacts were reported.

Case studies with strong collaborations in the Global South (*Irrigation Technology Project* in Fig. 2, and *Marine NbS Project* and *Blue Economy PA* in Fig. 5) reported a broader range of potential contributions to the SDGs and their sub-targets. In addition to SDGs related to their natural resource focus (e.g., SDG 2: Zero Hunger, SDG 14: Life Below Water),

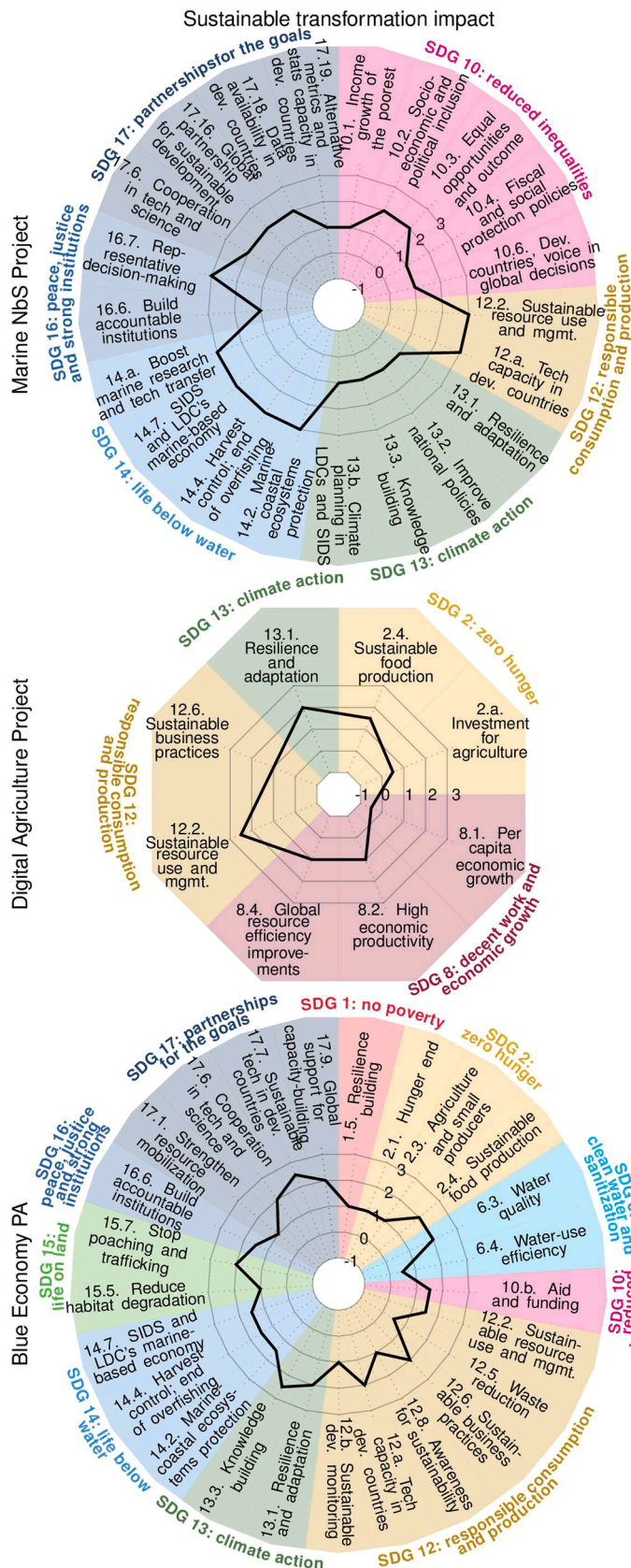


Fig. 5. Impact radars for sustainable transformation impacts (impact criteria rated from –3 (major negative impact) to +3 (major positive impact)).

The Marine NbS Project anticipated **strong positive contributions** to **SDG 12**: Responsible Consumption and Production, **SDG 14**: Life Below Water, and **SDG 16**: Peace, Justice, and Strong Institutions. These include achieving sustainable management and efficient use of natural resources (SDG 12.2), supporting developing countries in strengthening scientific and technological capacity (SDG 12.a), sustainably managing and protecting marine and coastal ecosystems (SDG 14.2), effectively regulating harvesting and ending overfishing (SDG 14.4), increasing economic benefits from sustainable marine resource use (SDG 14.7), increasing scientific knowledge, research capacity, and marine technology transfer (SDG 14.a), and ensuring responsive, inclusive, and participatory decision-making (SDG 16.7). **Moderate positive contributions** were anticipated for **SDG 10**: Reduced Inequalities and **SDG 17**: Partnerships for the Goals, addressing social, economic, and political inclusion (SDG 10.2), ensuring equal opportunity and reducing inequalities (SDG 10.3), enhancing cooperation in science and technology (SDG 17.6), strengthening the Global Partnership for Sustainable Development (SDG 17.18). Collectively, these contributions were seen to position Marine NbS Project as a key initiative in **advancing the sustainable use and conservation of marine ecosystems and resources**.

The Digital Agriculture Project was expected to make **strong positive contributions** to **SDG 12**: Responsible Consumption and Production, specifically achieving sustainable management and efficient resource use (SDG 12.2). **Moderate positive contributions** were also expected for **SDG 2**: Zero Hunger, by ensuring sustainable food production systems and biomass sustainability (SDG 2.4), and **SDG 13**: Climate Action, by strengthening resilience and adaptive capacity through carbon storage measures (SDG 13.1). **Weak negative impacts** were anticipated for **SDG 8**: Decent Work and Economic Growth, specifically sustaining per capita economic growth (SDG 8.1), due to profitability challenges, which could be mitigated through appropriate policies. Collectively, these efforts aimed to **advance integrated, diversified, and automated agricultural systems for sustainable development**.

The Blue Economy PA anticipated moderate to **strong positive contributions** for **SDG 13**: Climate Action and **SDG 17**: Partnerships for the Goals. These include strengthening resilience and adaptive capacity (SDG 13.1), improving education, awareness-raising, and institutional capacity (SDG 13.3), enhancing cooperation in science and technology (SDG 17.6), promoting environmentally sound technologies to developing countries (SDG 17.7), and providing effective international capacity-building support (SDG 17.9). **Moderate positive contributions** were identified for **SDG 2**: Zero Hunger, **SDG 6**: Clean Water and Sanitation, **SDG 12**: Responsible Consumption and Production, **SDG 14**: Life Below Water, **SDG 15**: Life on Land, and **SDG 16**: Peace, Justice, and Strong Institutions. These included improving water quality by reducing pollution (SDG 6.3), sustainably managing marine and coastal ecosystems (SDG 14.2), and ending poaching and trafficking of protected species (SDG 15.7). Collectively, the efforts of the program area aim to **emphasize sustainable, equitable, and just use of marine and aquatic resources, with efforts extending to co-creation and participatory research for broader societal impacts**.

these case studies also highlighted contributions to developmental goals such as SDG 10: Reduced Inequalities and SDG 17: Partnerships for the Goals. This underscores the capability of societal RIA to reveal the added value of such research, as well as the difficulties of applying the SDGs in a national context.

Participants often lacked familiarity with SDG targets and indicators prior to the workshops, underscoring the importance of tailored materials (e.g., see Supplementary Indicator Set). Although selecting relevant SDG sub-targets proved challenging—balancing the tension between oversimplification and highly specific indicators—participants emphasized the value of this exercise for proposal writing and project reporting. Aligning potential impacts with global sustainability goals was seen as a means to support more impactful, informed, and comparable research planning.

### 5.3. Enablers and barriers to impact

Each case study identified enablers and barriers to research impact for a number of categories of impact-generating processes (Table 3). Looking at the discussed factors across cases, a few general insights can be drawn. Individual key actors, their capacities, and relationships among and with them emerged as most relevant with regards to the achievement of impact. The nature of evidence and decision context were additional critical aspects. Most enablers related to the existence and establishment of reliable, trustful relationships. Adequate, context-sensitive training on methods and technological demonstration, related to the capacities of actors, structures for conflict resolution among stakeholders, and incentives regarding the implementation of relevant approaches for the sustainable use of natural resources, were similarly mentioned by the participants. The quality, salience and accessibility of information, and the effective exchange of relevant information, was another important area supporting the generation of impact.

Overall, the results underline the complexity and context-specific nature of factors and processes leading to impacts, rendering the use of common criteria and of comparisons among projects and different contexts difficult. Still, the exercise was valuable for the structured reflection on existing conditions, available resources, and necessary preconditions to achieve certain impacts. It also allowed participants to reflect on factors obstructing these goals and strategies to leverage resources to overcome these barriers, e.g. through strategic partnerships or communication strategies. Lastly, it brought existing gaps in knowledge and remaining uncertainties to the fore, showing where additional information is needed to more fully understand how and what kinds of impacts can be achieved.

## 6. Discussion and Conclusions

This study aimed to address a gap in RIA for interdisciplinary NRM research. RIA for transdisciplinary research has advanced the systematic reflection of research processes, stakeholder engagement, and co-creation (e.g., Belcher et al., 2019; Schäfer et al., 2021), often emphasizing process quality and proximal outcomes. In contrast, RIA approaches developed for agricultural research, such as ImpresS and ASIRPA, explicitly engage with impact pathways and broader societal effects (Faure et al., 2020; Joly et al., 2015). Building on these foundations, the applied ex ante RIA approach extends this logic beyond agricultural research to the wider field of interdisciplinary NRM. Unlike field-bound existing approaches, it integrates the structured use of established and comprehensive indicator sets to make anticipated impacts explicit across multiple societal impact levels, support the identification of synergies and trade-offs, and enable comparability across cases and contexts. At the same time, the approach shares with existing RIA methods a contribution-oriented logic and a participatory design. The application in four case studies across two institutes demonstrates the feasibility of the presented RIA approach to be applied in varying contexts.

### 6.1. Leveraging repurposed indicator sets: uncovering benefits in new contexts

The established indicator sets proved useful in supporting systemic and structured planning for impactful research, fostering an improved joint understanding of impact potentials (MacPherson et al., 2025). While the discussion and assessment of impacts was predominantly anchored at the criteria level, indicators function as a means to explicate potential impacts and support shared understanding among participants. The general formulation of these sets also allowed criteria developed for terrestrial contexts to be applied in marine research, where comparable sets are lacking. Participants added case-specific criteria where the generalized set did not fit. Many participants only realized their research's potential impacts when explicitly discussing them in relation to the indicator sets. This realization often led to a broader awareness of possible project impacts, as well as the enablers, barriers, and strategies necessary to achieve them. It also revealed nuanced differences among participants in their assumptions.

In the *Irrigation Technology Project*, the criteria and indicators applied in the RIA were further operationalized within the project itself to conduct an impact assessment (i.e., FoPIA) as part of its research activities, demonstrating that the approach can serve both as an ex ante planning tool and as a basis for embedded analytical assessment.

Participants recognized the importance of reflecting and demonstrating potential social and economic impacts alongside the environmental impacts, which were the primary focus. System-level impacts were referred to as most relevant to policymakers, keeping research pertinent to policy and decision-making contexts (Pahl-Wostl et al., 2013; Vinke-de Kruijf et al., 2020). The exercise also proved relevant for proposal writing: the *Digital Agriculture Project* incorporated a simplified version of the materials into the proposal for its second phase. By aligning potential impacts with societal goals, structured criteria support more impact-oriented and comparable research plans, and provide a framework for articulating how projects contribute to societal transformations (Chapman et al., 2020).

Case studies with strong collaborations in the Global South, such as *Marine NbS Project* and *Blue Economy PA*, identified a broader range of potential contributions to the SDGs (Section 5.2.3). This finding underscores societal RIA's ability to uncover and present the added value, such as capacity development (Vallejo and Wehn, 2016), of such research.

Further, applying established indicator sets can offer a foundation for potential connections to monitoring, project reporting and ex post assessments (Rasmussen et al., 2017) across extended time horizons. The majority of participants acknowledged that societal impacts would only be assessable in the distant future, if at all, with only some social, economic, or ecological impacts potentially being recognized by the projects' conclusion (see Table SM3).

### 6.2. Navigating interdisciplinary challenges: usability of RIA for complex, interdisciplinary research

The RIA approach helped address persistent cognitive and collaborative challenges in interdisciplinary research. When participants were asked about the effects of cognitive (e.g., conceptual, communication) and collaborative demands on interdisciplinary research (see Section SM6.1), all but two agreed that these demands lead to lower efficiency, underscoring this as an ongoing challenge (Graybill et al., 2006; Leahey et al., 2017). By offering a structured framework, the approach supported research teams in facilitating systematic discussions, aligning goals and developing a shared language. Participants noted the workshops' effectiveness in defining objectives, clarifying roles, and organizing research activities. One of the approach's key strengths lies in its adaptability across varying contexts and scales. However, participants highlighted challenges related to increased complexity at the program level, emphasizing the need for methodological adaptations to better

support such applications. At the same time, others saw value in exploring linkages and synergies across multiple program areas, pointing to opportunities for broader institutional application.

Participants expressed mixed opinions on whether interdisciplinary research is of lower quality (see Section SM6.1), reflecting persistent assumptions about research quality being tied to productivity metrics (e. g., publication numbers) and the trade-off between societal relevance and scientific reputation (Fontana et al., 2022). Reflecting on societal impacts, as done in this study, can illuminate the broader contributions of interdisciplinary research. However, such reflections remain isolated and invisible if not institutionalized by research organizations and/or funders (Rau et al., 2018).

Only half of the participants reported feeling supported and rewarded for the additional time and effort required for interdisciplinary research (see Section SM6.1). This finding points to opportunities for improvement. Institutionalizing RIA approaches can provide critical support for interdisciplinary teams by streamlining the substantial effort required for planning societally relevant research such as in the area of NRM (Haythornthwaite, 2006), enabling communication across disciplinary boundaries in interdisciplinary teams and projects, and recognizing their unique contributions.

### 6.3. Limitations and future research

A key limitation of our study lies in its application within a research context with limited institutional support and infrastructure for reflecting on societal impact. While this highlights the applicability of the RIA approach under constrained conditions, it also limited the depth of analysis and sustained engagement. Participatory RIA remains resource-intensive, requiring significant time for workshops, facilitation, and follow-up, which posed challenges despite iterative methodological refinements. In addition, case study selection relied on voluntary participation, potentially introducing self-selection bias and limiting representativeness across interdisciplinary research contexts.

Future research should further explore the operationalization of indicator-based RIA, particularly at the indicator level, and assess its influence on research outcomes. Additional work is needed on how to effectively integrate and reward impact-oriented practices, especially in collaborations with the Global South. Studying the trajectory of the case study research organizations as they develop a culture of impact (Blundo-Canto et al., 2019; Ferré et al., 2025) and institutional impact literacy (Bayley and Phipps, 2019) could provide valuable insights into and steer institutional transformation. Finally, comparative studies could examine different participation models to better understand trade-offs between inclusiveness and efficiency in RIA processes.

### 6.4. Insights and conclusions for the science system

The case studies indicate what institutionalizing RIA would require in practice. Individual capacity gains were achieved, since most participants reported gaining knowledge of RIA through the workshops, with many expressing confidence in applying the approach independently (see Tables SM4 and SM5). The subsequent use of workshop outputs, however, varied considerably. Uptake occurred where results could enter a time-bound process, as in the *Digital Agriculture Project's* second-phase proposal. Across all four cases, and despite being discussed during the workshops, none sustained reflection loops or monitoring. Participation required approximately 18 h per person, alongside considerably greater facilitation and synthesis effort by the research team, and exercises remained incomplete in every case despite iterative streamlining of the method.

Following the workshops, both participating institutes initiated further activities related to societal impact. ZMT established a CoARA (coalition of advancing research assessment) working group on societal impacts and applied elements of the ex ante impact pathway methodology in planning its program areas; ZALF joined the GTPF (German

association for transdisciplinary and participatory research) working group on impact; and elements of the methodology were used in a proposal to a programmatic funding line of the Leibniz Association. In the terms of Bayley and Phipps (2019), individual impact literacy advanced among participants, while institutional literacy remains at a supportive level, with initial steps toward enabling structures. Positioned against the trajectories of culture of impact (Ferré et al., 2025), both institutes sit early in the development phase. Unlike the institutions they analysed (CIRAD, Embrapa and AGROSAVIA), impact-orientation in our case was introduced from within research practice rather than through institutional decisions mainly driven by accountability demands from government and funders. It advanced through application and advocacy rather than strategic decision. Hence our study suggests that a culture of impact can be initiated bottom-up, but also that this route depends on individual initiative in the absence of dedicated resources and formalized processes. This absence of resources and processes may explain the discontinued reflection loops in our cases.

Sustaining such an emerging culture requires institutional measures (Blundo-Canto et al., 2019; Ferré et al., 2025). Institutions need to embed impact considerations in strategic plans, form dedicated impact teams, and allocate resources that sustain engagement with RIA beyond individual applications. Capacity building through training and support mechanisms is equally necessary, as is the continued methodological development required to apply RIA at programmatic level or in varying contexts. The approach presented here contributes to this need by offering an adaptable and widely applicable method.

Support from funders is equally crucial in advancing impactful research. All participants familiar with RIA prior to the workshops attributed their awareness to grant application requirements (see Table SM6). Hence, making structured reflection on societal impacts a mandatory component of funding applications could foster impact-orientation, streamline evaluation processes, and ensure alignment with impact objectives. Additionally, research planning-specific budgets, such as seed grants, funding for RIA activities during and after research projects, and adaptable funding mechanisms that allow projects to respond to changing contexts, can better support research initiatives aiming to deliver societal impact.

Lastly, a fundamental shift is needed from traditional productivity metrics to criteria that reflect real research quality, as advocated by CoARA (Arentoft et al., 2022), in the European research landscape. This shift is critical to addressing the mismatch between funders' demand for societal impact and the persistent focus on peer-reviewed articles.

The findings highlight the value of impact-orientation for interdisciplinary NRM research. Anticipating potential societal impacts encourages researchers to reflect on how their work relates to broader environmental management goals, consider trade-offs and synergies across sustainability dimensions, and align research activities with shared societal objectives. The framework presented here is therefore intended as an invitation to researchers, project teams, and research managers to actively engage with the anticipation of societal impacts and experiment with structured impact-oriented reflection in their own research contexts.

### CRedit authorship contribution statement

**Lena Pfeifer:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Sebastian Ferse:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Katharina Helming:** Writing – review & editing, Writing – original draft, Funding acquisition, Conceptualization.

### Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT for

language editing, and Claude (Anthropic) for language editing and for support in restructuring the manuscript, and for assistance in identifying literature. After using these tools the authors reviewed and edited the content and take full responsibility for the content of the publication.

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## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.envsci.2026.104512](https://doi.org/10.1016/j.envsci.2026.104512).

## Data availability

The authors do not have permission to share data.

## References

- Alvarez, S., Douthwaite, B., Thiele, G., Mackay, R., Córdoba, D., Tehelen, K., 2010. Participatory impact pathways analysis: a practical method for project planning and evaluation. *Dev. Pract.* 20 (8), 946–958. <https://doi.org/10.1080/09614524.2010.513723>.
- Arentoft, M., Berghmans, S., Borrell-Damian, L., Bottaro, S., Faure, J., Gaillard, V., Glinos, K., Albacete, J., Morais, R., Morris, J., 2022. Agreement on reforming research assessment. *Zenodo* 10. <https://doi.org/10.5281/zenodo.1348072>.
- Barret, D., Blundo-Canto, G., Dabat, M.H., Devaux-Spatarakis, A., Faure, G., Hainzelin, E., Mathé, S., Temple, L., Toillier, A., Triomphe, B., & Vall, E. (2018). *Methodological guide to ex post impact evaluation of agricultural research in developing countries*. <https://doi.org/10.19182/agritrop/00006>.
- Bayley, J., Phipps, D., 2019. Extending the concept of research impact literacy: levels of literacy, institutional role and ethical considerations. *Emerald Open. Res.* 1 (14). <https://doi.org/10.1108/eor-03-2023-0005>.
- Belcher, B.M., Claus, R., Davel, R., Ramirez, L.F., 2019. Linking transdisciplinary research characteristics and quality to effectiveness: a comparative analysis of five research-for-development projects. *Environ. Sci. Policy* 101, 192–203. <https://doi.org/10.1016/j.envsci.2019.08.013>.
- Belcher, B.M., Rasmussen, K.E., Kemshaw, M.R., Zornes, D.A., 2016. Defining and assessing research quality in a transdisciplinary context. *Res. Eval.* 25 (1), 1–17. <https://doi.org/10.1093/reseval/rvv025>.
- Bettencourt, L.M., Kaur, J., 2011. Evolution and structure of sustainability science. *Proc. Natl. Acad. Sci. USA* 108 (49), 19540–19545. <https://doi.org/10.1073/pnas.1102712108>.
- Blundo-Canto, G., de Roméont, A., Hainzelin, E., Faure, G., Monier, C., Triomphe, B., Barret, D., & Vall, E. (2020). *ImpresS ex ante methodological guide to ex ante co-construction of development oriented research impact pathways (second version)*. <https://doi.org/10.19182/agritrop/00147>.
- Blundo-Canto, G., Triomphe, B., Faure, G., Barret, D., de Roméont, A., Hainzelin, E., 2019. Building a culture of impact in an international agricultural research organization: process and reflective learning. *Res. Eval.* 28 (2), 136–144. <https://doi.org/10.1093/reseval/rvy033>.
- Bornmann, L., 2012. What is societal impact of research and how can it be assessed? a literature survey. *J. Am. Soc. Inf. Sci. Technol.* 64 (2), 217–233. <https://doi.org/10.1002/asi.22803>.
- Brandt, P., Ernst, A., Gralla, F., Luederitz, C., Lang, D.J., Newig, J., Reinert, F., Abson, D. J., von Wehrden, H., 2013. A review of transdisciplinary research in sustainability science. *Ecol. Econ.* 92, 1–15. <https://doi.org/10.1016/j.ecolecon.2013.04.008>.
- Brennan, M., Rondon-Sulbaran, J., 2019. Transdisciplinary research: Exploring impact, knowledge and quality in the early stages of a sustainable development project. *World Dev.* 122, 481–491. <https://doi.org/10.1016/j.worlddev.2019.06.001>.
- Cameron, D.B., Mishra, A., Brown, A.N., 2015. The growth of impact evaluation for international development: how much have we learned? *J. Dev. Eff.* 8 (1), 1–21. <https://doi.org/10.1080/19439342.2015.1034156>.
- Cash, D., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Jäger, J., 2002. Saliency, credibility, legitimacy and boundaries: linking research, assessment and decision making. *Assess. Decis. Mak.* (Novemb. 2002). <https://doi.org/10.2139/ssrn.372280>.
- Chams, N., Guesmi, B., Gil, J.M., 2020. Beyond scientific contribution: Assessment of the societal impact of research and innovation to build a sustainable agri-food sector. *J. Environ. Manag.* 264, 110455. <https://doi.org/10.1016/j.jenvman.2020.110455>.
- Chapman, G.R., Cully, A., Kosiol, J., Macht, S.A., Chapman, R.L., Fitzgerald, J.A., Gertsen, F., 2020. The wicked problem of measuring real-world research impact: using sustainable development goals (SDGs) and targets in academia. *J. Manag. Organ.* 26 (6), 1030–1047. <https://doi.org/10.1017/jmo.2020.16>.
- CICES. (2018). *Towards a Common International Classification of Ecosystem Services (CICES) for Integrated Environmental and Economic Accounting: V5.1 Spreadsheet* <https://cices.eu/resources/>.
- Commission, E. (2018). *A new Horizon for Europe - Impact Assessment of the 9th EU Framework Programme for Research and Innovation*. <https://doi.org/10.2777/978720>.
- Cooke, S.J., Rytwinski, T., Taylor, J.J., Nyboer, E.A., Nguyen, V.M., Bennett, J.R., Young, N., Aitken, S., Auld, G., Lane, J.-F., Prior, K.A., Smokorowski, K.E., Smith, P. A., Jacob, A.L., Browne, D.R., Blais, J.M., Kerr, J.T., Ormeci, B., Alexander, S.M., Smol, J.P., 2020. On “success” in applied environmental research — What is it, how can it be achieved, and how does one know when it has been achieved? *Environ. Rev.* 28 (4), 357–372. <https://doi.org/10.1139/er-2020-0045>.
- CSIRO. (2020). *Impact Evaluation Guide*. [https://www.csiro.au/-/media/About/Files/Our-impact-framework/CSIROImpactEvaluationGuide\\_WEB.pdf](https://www.csiro.au/-/media/About/Files/Our-impact-framework/CSIROImpactEvaluationGuide_WEB.pdf).
- Cvitanovic, C., Shellock, R.J., Mackay, M., van Putten, E., Karcher, D.B., Dickey-Collas, M., Ballesteros, M., 2021. Strategies for building and managing ‘trust’ to enable knowledge exchange at the interface of environmental science and policy. *Environ. Sci. & Policy* 123, 179–189. <https://doi.org/10.1016/j.envsci.2021.05.020>.
- Daedlow, K., Podhora, A., Winkelmann, M., Kopfmüller, J., Walz, R., Helming, K., 2016. Socially responsible research processes for sustainability transformation: an integrated assessment framework. *Curr. Opin. Environ. Sustain.* 23, 1–11. <https://doi.org/10.1016/j.cosust.2016.09.004>.
- Douthwaite, B., Kuby, T., van de Fliert, E., Schulz, S., 2003. Impact pathway evaluation: an approach for achieving and attributing impact in complex systems. *Agric. Syst.* 78 (2), 243–265. [https://doi.org/10.1016/S0308-521X\(03\)00128-8](https://doi.org/10.1016/S0308-521X(03)00128-8).
- Eriksson, M., Ahlback, A., Silow, N., & Svane, M. (2020). *SDG Impact Assessment Tool: GUIDE 1.0*. <http://www.unsd-n-ne.org/wp-content/uploads/2020/11/SDG-Impact-Assessment-Tool-Guide-1-0-final-ver02-mini.pdf>.
- European Commission. (2021). *EU Missions in Horizon Europe*. Retrieved 27.04.2022 from [https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe\\_en](https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe_en).
- FAO. (2013). *SAFA Indicators: Sustainability Assessment of Food and Agriculture* [https://www.fao.org/fileadmin/templates/nr/sustainability\\_pathways/docs/SAFA\\_Indicators\\_final\\_19122013.pdf](https://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/SAFA_Indicators_final_19122013.pdf).
- FAO OED. (2020). *Evaluation of FAO's contribution to Sustainable Development Goal 2 - "End hunger, achieve food security and improved nutrition and promote sustainable agriculture"*. <https://www.fao.org/evaluation/highlights/highlights-detail/en/c/1315235/>.
- Faure, G., Blundo-Canto, G., Devaux-Spatarakis, A., Le Guerroué, J.L., Mathé, S., Temple, L., Toillier, A., Triomphe, B., Hainzelin, E., 2020. A participatory method to assess the contribution of agricultural research to societal changes in developing countries. *Res. Eval.* 29 (2), 158–170. <https://doi.org/10.1093/reseval/rvz036>.
- Ferré, M., Blundo-Canto, G., Rodrigues, G.S., Ramírez-Gómez, M.-M., Vedovoto, G.L., Agudelo-Chocontá, B.-E., Marques, D.V., Flores, R.M.V., Rodríguez-Borray, G.-A., De Souza, M.O., 2025. Culture of impact in agricultural research organisations: what for and how? *Res. Policy* 54 (1), 105140. <https://doi.org/10.1016/j.respol.2024.105140>.
- Ferretti, J., K., D., Kopfmüller, J., Winkelmann, M., Podhora, A., Walz, R., Bertling, J., & Helming, K. (2023). *Framework for reflection on research with societal responsibility* (BMBF project “LeNa - Sustainability management in non-university research institutions”, translation of the German version “Reflexionsrahmen für Forschen in gesellschaftlicher Verantwortung”, first published in 2016 (Ferretti et al. 2016), Issue. [https://www.nachhaltig-forschen.de/assets/lena\\_nachhaltig-forschen/user\\_upload/20240216\\_LeNa-Reflexionsrahmen\\_ENG\\_v03\\_HighRes.pdf](https://www.nachhaltig-forschen.de/assets/lena_nachhaltig-forschen/user_upload/20240216_LeNa-Reflexionsrahmen_ENG_v03_HighRes.pdf).
- Ferre, S., & Pfeifer, L. (2024). *Ex ante Impact Pathways. A guide to conducting workshops for impact planning. Prepared as part of the LeNa Shape project*. <https://doi.org/10.21244/zmt.2024.001>.
- Fontana, M., Iori, M., Sciabolazza, V.L., Souza, D., 2022. The interdisciplinarity dilemma: public versus private interests. *Res. Policy* 51 (7), 104553. <https://doi.org/10.1016/j.respol.2022.104553>.
- Fryirs, K.A., Brierley, G.J., Dixon, T., 2019. Engaging with research impact assessment for an environmental science case study. *Nat. Commun.* 10 (1), 4542. <https://doi.org/10.1038/s41467-019-12020-z>.
- Glaser, M., Christie, P., Diele, K., Dsikowitzky, L., Ferse, S., Nordhaus, I., Schlüter, A., Mañez, K.S., Wild, C., 2012. Measuring and understanding sustainability-enhancing processes in tropical coastal and marine social-ecological systems. *Curr. Opin. Environ. Sustain.* 4 (3), 300–308. <https://doi.org/10.1016/j.cosust.2012.05.004>.

- Graybill, J.K., Dooling, S., Shandas, V., Withey, J., Greve, A., Simon, G.L., 2006. A rough guide to interdisciplinarity: graduate student perspectives. *BioScience* 56 (9), 757–763. [https://doi.org/10.1641/0006-3568\(2006\)56\[757:Argtig\]2.0.Co;2](https://doi.org/10.1641/0006-3568(2006)56[757:Argtig]2.0.Co;2).
- Haythornthwaite, C., 2006. Learning and knowledge networks in interdisciplinary collaborations. *J. Am. Soc. Inf. Sci. Technol.* 57 (8), 1079–1092. <https://doi.org/10.1002/asi.20371>.
- Henzler, K., Maier, S.D., Jäger, M., Horn, R., 2020. SDG-Based Sustainability Assessment Methodology for Innovations in the Field of Urban Surfaces. *Sustainability* 12 (11), 4466. <https://doi.org/10.3390/su12114466>. <https://www.mdpi.com/2071-1050/12/11/4466>.
- Hoffmann, S., Klein, J.T., Pohl, C., 2019. Linking transdisciplinary research projects with science and practice at large: introducing insights from knowledge utilization. *Environ. Sci. Policy* 102, 36–42. <https://doi.org/10.1016/j.envsci.2019.08.011>.
- ILRI. (2020). *The Impact of the International Livestock Research Institute* (C)J. McIntire & D. Grace, Eds(C). <https://www.ilri.org/ILRI-research-impact>.
- Jacobs, L., Frickel, S., 2009. Interdisciplinarity: a critical assessment. *Annu. Rev. Sociol.* 35 (1), 43–65. <https://doi.org/10.1146/annurev-soc-070308-115954>.
- Joly, P.B., Gaunand, A., Colinet, L., Larédo, P., Lemarié, S., Matt, M., 2015. ASIRPA: A comprehensive theory-based approach to assessing the societal impacts of a research organization. *Res. Eval.* 24 (4), 440–453. <https://doi.org/10.1093/reseval/rvv015>.
- Karcher, D.B., Cvitanovic, C., Colvin, R.M., van Putten, I.E., Reed, M.S., 2021. Is this what success looks like? Mismatches between the aims, claims, and evidence used to demonstrate impact from knowledge exchange processes at the interface of environmental science and policy. *Environ. Sci. Policy* 125, 202–218. <https://doi.org/10.1016/j.envsci.2021.08.012>.
- Kny, J., Claus, R., Harris, J., Schäfer, M., 2023. Assessing societal effects: Lessons from evaluation approaches in transdisciplinary research fields. *Gaia-Ecol. Perspect. Sci. Soc.* 32 (1), 178–185. <https://doi.org/10.14512/gaia.32.1.17>.
- Krause, G., Schupp, M.F., 2019. Evaluating knowledge transfer at the interface between science and society. *Gaia-Ecol. Perspect. Sci. Soc.* 28 (3), 284–293. <https://doi.org/10.14512/gaia.28.3.9>.
- Leahey, E., Beckman, C.M., Stanko, T.L., 2017. Prominent but less productive: the impact of interdisciplinarity on scientists' research. *Adm. Sci. Q.* 62 (1), 105–139. <https://doi.org/10.1177/0001839216665364>.
- Lux, A., Schäfer, M., Bergmann, M., Jahn, T., Marg, O., Nagy, E., Ransiek, A.-C., Theiler, L., 2019. Societal effects of transdisciplinary sustainability research—How can they be strengthened during the research process? *Environ. Sci. Policy* 101, 183–191. <https://doi.org/10.1016/j.envsci.2019.08.012>.
- Maag, S., Alexander, T.J., Kase, R., Hoffmann, S., 2018. Indicators for measuring the contributions of individual knowledge brokers. *Environ. Sci. Policy* 89, 1–9. <https://doi.org/10.1016/j.envsci.2018.06.002>.
- Mach, K.J., Lemos, M.C., Meadow, A.M., Wyborn, C., Klenk, N., Arnott, J.C., Ardoon, N. M., Fieseler, C., Moss, R.H., Nichols, L., Stults, M., Vaughan, C., Wong-Parodi, G., 2020. Actionable knowledge and the art of engagement. *Curr. Opin. Environ. Sustain.* 42, 30–37. <https://doi.org/10.1016/j.cosust.2020.01.002>.
- MacPherson, J., Rosman, A., Helming, K., Burkhard, B., 2025. A participatory impact assessment of digital agriculture: a Bayesian network-based case study in Germany. *Agric. Syst.* 224, 104222. <https://doi.org/10.1016/j.agsy.2024.104222>.
- Matt, M., Robinson, D.K.R., Joly, P.B., Van Dis, R., Colinet, L., 2023. ASIRPA in the making or how to empower researchers to steer research towards desired societal goals. *Res. Eval.* 32 (2), 412–425. <https://doi.org/10.1093/reseval/rvad004>.
- Mazzucato, M. (2018). *Mission-oriented research & innovation in the European Union: A problem-solving approach to fuel innovation-led growth*. Publications Office. <https://data.europa.eu/doi/10.2777/360325>.
- Newig, J., Jahn, S., Lang, D.J., Kahle, J., Bergmann, M., 2019. Linking modes of research to their scientific and societal outcomes. Evidence from 81 sustainability-oriented research projects. *Environ. Sci. Policy* 101, 147–155. <https://doi.org/10.1016/j.envsci.2019.08.008>.
- Norström, A.V., Cvitanovic, C., Löf, M.F., West, S., Wyborn, C., Balvanera, P., Bednarek, A.T., Bennett, E.M., Biggs, R., de Bremond, A., 2020. Principles for knowledge co-production in sustainability research. *Nat. Sustain.* 3 (3), 182–190. <https://doi.org/10.1038/s41893-019-0448-2>.
- OECD, 2019. Reference framework for assessing the scientific and socio-economic impact of research infrastructures. OECD Science, Technology and Industry Policy Papers. Organisation for Economic Co-Operation and Development (OECD). <https://doi.org/10.1787/3ffee43b-en>. [https://www.oecd-ilibrary.org/science-and-technology/reference-framework-for-assessing-the-scientific-and-socio-economic-impact-of-research-infrastructures\\_3ffee43b-en](https://www.oecd-ilibrary.org/science-and-technology/reference-framework-for-assessing-the-scientific-and-socio-economic-impact-of-research-infrastructures_3ffee43b-en).
- Okamura, K., 2019. Interdisciplinarity revisited: evidence for research impact and dynamism. *Palgrave Commun.* 5 (1), 141. <https://doi.org/10.1057/s41599-019-0352-4>.
- Owen, R., Macnaghten, P., Stilgoe, J., 2012. Responsible research and innovation: from science in society to science for society, with society. *Sci. Public. Policy* 39 (6), 751–760. <https://doi.org/10.1093/scipol/scs093>.
- Pahl-Wostl, C., Becker, G., Knieper, C., Sendzimir, J., 2013. How multilevel societal learning processes facilitate transformative change: a comparative case study analysis on flood management. *Ecol. Soc.* 18 (4). <https://doi.org/10.5751/Es-05779-180458>.
- Pfeifer, L., Helming, K., 2024. Effective mission-oriented research: a new framework for systemic research impact assessment. *Res. Eval.* 33, 1–15. <https://doi.org/10.1093/reseval/rvae003>.
- Plummer, R., Blythe, J., Gurney, G.G., Witkowski, S., Armitage, D., 2022. Transdisciplinary partnerships for sustainability: an evaluation guide. *Sustain. Sci.* 17 (3), 955–967. <https://doi.org/10.1007/s11625-021-01074-y>.
- Rasmussen, L.V., Bierbaum, R., Oldekop, J.A., Agrawal, A., 2017. Bridging the practitioner-researcher divide: indicators to track environmental, economic, and sociocultural sustainability of agricultural commodity production. *Glob. Environ. Change-Human. Policy Dimens.* 42, 33–46. <https://doi.org/10.1016/j.gloenvcha.2016.12.001>.
- Rau, H., Goggins, G., Fahy, F., 2018. From invisibility to impact: recognising the scientific and societal relevance of interdisciplinary sustainability research. *Res. Policy* 47 (1), 266–276. <https://doi.org/10.1016/j.respol.2017.11.005>.
- Razmgir, M., Panahi, S., Ghalichi, L., Mousavi, S.A.J., Sedghi, S., 2021. Exploring research impact models: a systematic scoping review. *Res. Eval.* 30 (4), 443–457. <https://doi.org/10.1093/reseval/rvab009>.
- Reed, M. (2019). *3 i's advanced stakeholder analysis*. Retrieved 6.12.2022 from <https://www.fasttrackimpact.com/post/2019/11/19/3-i-s-stakeholder-analysis-advanced-analysis-reveals-more-than-ever-before-about-who-yo>.
- Reed, M.S., Ferré, M., Martín-Ortega, J., Blanche, R., Lawford-Rolfe, R., Dallimer, M., Holden, J., 2021. Evaluating impact from research: a methodological framework. *Res. Policy* 50 (4), 104147. <https://doi.org/10.1016/j.respol.2020.104147>.
- Reed, M.S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C.H., Stringer, L.C., 2009. Who's in and why? A typology of stakeholder analysis methods for natural resource management. *J. Environ. Manag.* 90 (5), 1933–1949. <https://doi.org/10.1016/j.jenvman.2009.01.001>.
- Rova, C. (2006). The Importance of Trust and Legitimacy in the Management of Common-pool Resources (CPR): Lessons learned from implementation of a fishery co-management system in a complex society. Biennial conference of the International Association for the Study of Common Property: 19/06/2006-23/06/2006.
- Schäfer, M., Bergmann, M., Theiler, L., 2021. Systematizing societal effects of transdisciplinary research. *Res. Eval.* 30 (4), 484–499. <https://doi.org/10.1093/reseval/rvab019>.
- Smith, T.F., Carter, R.W., Thomsen, D.C., Mayes, G., Nursey-Bray, M., Whisson, G., Jones, R., Dovers, S., O'Toole, K., 2009. Enhancing science impact in the coastal zone through adaptive learning. *J. Coast. Res.* 1306–1310. <https://www.jstor.org/stable/25738000>.
- Temper, L., McGarry, D., Weber, L., 2019. From academic to political rigour: insights from the 'Tarot' of transgressive research. *Comment. Ecol. Econ.* 164, 106379. <https://doi.org/10.1016/j.ecolecon.2019.106379>.
- Thierfelder, J., Matthews, B., Risch, A.C., Hoffmann, S., 2026. Muddling through: a typology of interdisciplinary research practices in environmental sciences. *Environ. Sci. & Policy* 177, 104342. <https://doi.org/10.1016/j.envsci.2026.104342>.
- United Nations Statistical Commission. (2022). *SDG Indicators—Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development (after 2022 refinement)* <https://unstats.un.org/sdgs/indicators/indicators-list/>.
- Vallejo, B., Wehn, U., 2016. Capacity development evaluation: the challenge of the results agenda and measuring return on investment in the global south. *World Dev.* 79, 1–13. <https://doi.org/10.1016/j.worlddev.2015.10.044>.
- van Drooge, L., Spaapen, J., 2017. Evaluation and monitoring of transdisciplinary collaborations. *J. Technol. Transf.* 47 (3), 747–761. <https://doi.org/10.1007/s10961-017-9607-7>.
- Vinke-de Kruijf, J., Pahl-Wostl, C., Knieper, C., 2020. Wider learning outcomes of European climate change adaptation projects: a qualitative comparative analysis. *Environ. Innov. Soc. Transit.* 34, 270–297. <https://doi.org/10.1016/j.eist.2018.09.004>.
- Walker, T., Maredia, M., Kelley, T., Rovere, R.L., Templeton, D., Thiele, G., Douthwaite, B., 2008. *Strateg. Guid. Ex. Post. Impact Assess. Agric. Res.* <https://www.fao.org/3/i0276e/i0276e00.htm>.
- Walsh, J.C., Dicks, L.V., Raymond, C.M., Sutherland, W.J., 2019. A typology of barriers and enablers of scientific evidence use in conservation practice. *J. Environ. Manag.* 250, 109481. <https://doi.org/10.1016/j.jenvman.2019.109481>.
- Walter, A.I., Helgenberger, S., Wiek, A., Scholz, R.W., 2007. Measuring societal effects of transdisciplinary research projects: design and application of an evaluation method. *Eval. Program. Plan.* 30 (4), 325–338. <https://doi.org/10.1016/j.evalproplan.2007.08.002>.
- Weißhuhn, P., Helming, K., Ferretti, J., 2018. Research impact assessment in agriculture—A review of approaches and impact areas. *Res. Eval.* 27 (1), 36–42. <https://doi.org/10.1093/reseval/rvx034>.
- World Resources Institute. (2014). *Indicators of Sustainable Agriculture: A Scoping Analysis* <https://www.wri.org/data/indicators-sustainable-agriculture-scoping-analysis>.